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The Depths of the Milky Way*

By BART J. BOK

In June of this year we in South Africa received word of the tragic death of our good friend Lois Tripp Slocum. While we had known of her illness, we had not realized that death would come so soon. Then news came from home about how Lois Slocum had carried on her work to the very last and how, through her splendid example of cheerful determination, she had strengthened the love and admiration which her friends and colleagues had long felt towards her. It is a rare tribute to Lois Slocum the astronomer, the teacher, and the person that the Faculty and her friends at Wilson College have decided to honor her through this Memorial Lecture, which I consider it a privilege to have been asked to deliver tonight.

Lois Slocum was born at New Bedford, Massachusetts, in a family rich in seafaring and astronomical tradition. She received her B.A. from Smith College in 1921 and her Ph.D. in astronomy from the University of California in 1930. In the years preceding World War II, she was first an instructor and then an assistant professor at Smith College, with a brief interim period of teaching at Wellesley College. In 1943, she became a Special Research Associate at the Radio Research Laboratory at Harvard, where she spent a year on a project relating to radio navigation. She joined the faculty of Wilson College in 1944 and served this college until the time of her death.

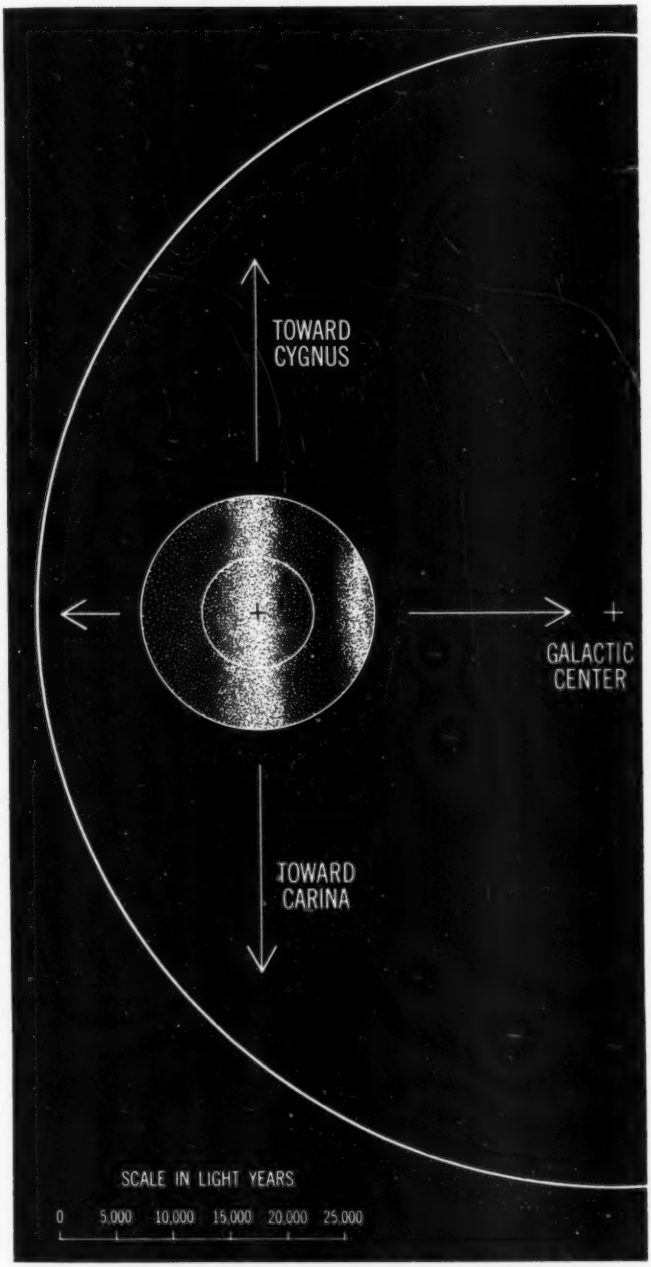
Lois Slocum's primary interest was the teaching of astronomy and, being a first-rate teacher, she read widely in astronomy and related fields. She was an active member of the American Astronomical Society and of the American Association of Variable Star Observers and the problems of celestial mechanics seemed to have a special attraction for her. But I think I am correct in saying that there was no other field in which she was so deeply interested as Milky Way research. Her project for the doctoral thesis was a study of the colors of faint stars in a section of the Milky Way, a project which, executed under the able direction of Dr. Robert J. Trumpler, was one of the first to demonstrate both the potential power of the color attack and the great difficulties that lay ahead in this area. When she returned to Harvard Observatory for a summer of research, there was no doubt that her primary interest continued to be in the study of dark nebulae and their effects. It seems fitting that for tonight's Memorial Lecture I have chosen the topic on

*The Lois Tripp Slocum Memorial Lecture delivered at Wilson College on November 6, 1951.

which, I sincerely believe, Lois Slocum would have liked to have me speak: The Depths of the Milky Way.

LOIS TRIPP SLOCUM

Our present knowledge of the structure of our Milky Way system is summarized fairly well by a diagram that I drew approximately two years ago. The band of the Milky Way delineates the central plane of our Milky Way or Galactic System. This star system, to which we sometimes refer as "Our Galaxy," measures approximately 100,000 light years across and our Sun is located well towards the edge of the system at a distance of 25,000 or 30,000 light years from the center. Our entire galaxy is rotating rapidly around an axis passing through the center and at right angles to the central Milky Way plane. This rotation, which produces the highly-flattened shape of our galaxy, is not a uniform one. Our Sun and its neighbors move around the center at a rate of approximately 150 miles per second and, for the explored part of our galaxy, the speed of rotation seems to increase as we consider stars closer to the center than our Sun and decrease as we move outward. The observed variation of speed of rotation with distance indicates in all prob-



NOTE: This diagram appeared originally in an article by the same author in *Scientific American*. It is used here by permission.

ability the presence of a large concentration of mass in the nucleus of our galaxy.

It has been estimated that the total number of stars in our galaxy is of the order of one hundred billion, but one should not deduce from this figure that only the stars count. The total mass of the gas and dust of interstellar space equals in all probability that of the stars in our Milky Way system. We find that in our sounding of the depths of our Milky Way, the gas and dust of the empty spaces in between the stars require about as much attention as the stars themselves.

Since the days of the Herschels, more than a century and a half ago, the study of the structure of our Milky Way system has been one of the half dozen or so central problems in the field of astronomy. Kapteyn's studies, begun about sixty years ago, laid the foundations for modern Milky Way research and, through the researches of Shapley, Lindblad and Oort, Trumpler, Stebbins and his associates, Baade and many others, there has emerged a fairly clear picture of the general outline and structure of our Milky Way system. Subject to further proof or disproof, it has been proposed as a working hypothesis that our Sun is located in a spiral arm of our galaxy. There are several lines of evidence that point towards this working model.

If we correct as best we can for the variable obscuration produced by the cosmic dust close to the galactic central plane, then we find that the stars thin out markedly with distance from the Sun in the direction away from the galactic center, that in direction at right angles to the direction of the center (that is toward Cygnus and Carina in the diagram) the numbers of stars per unit volume fluctuate without showing marked increases or decreases with increasing distance from the Sun, and that, finally, for the direction toward the galactic center the same numbers per unit volume fall off at first, to increase again at great distances from the Sun. All this fits nicely into the hypothesis that our Sun is located in a spiral arm of our galaxy.

The working hypothesis of the spiral structure of our galaxy finds independent support through comparative studies of stellar distribution for the region around our Sun and similar studies made on the distribution of stars and cosmic dust in the outer parts of spiral galaxies. Baade was the first to propose that in our own as well as in other galaxies we should distinguish clearly between two varieties of stellar families, Population I and Population II, and that this distinction is a basic one if we wish to compare our own and other galaxies.

Population I is characterized by the presence of highly luminous stars, such as the super-giant O and B stars with their associated emission nebulae, super-giant stars of other varieties, such as the long period Cepheid variables, galactic star clusters, and a plentiful supply of cosmic dust. Population II is much less spectacular. The most luminous stars in Population II are only about one-twentieth as bright intrinsically as the super-giants characteristic of Population I; O and B

stars, emission nebulae and clouds of cosmic dust are absent in a pure Population II. The intrinsically brightest stars in Population II are objects like the cluster-type variables and normal red giants, but dwarfish stars predominate.

Population I is found in the knots of spiral arms, in irregular galaxies such as the Magellanic Clouds and for the parts of our Milky Way system directly around our Sun. Population II is found in its purest form in globular clusters and appears to be characteristic for the amorphous ellipsoidal galaxies, the nuclear regions of the great spirals and, so it seems, for the nucleus of our own galactic system. Observation of nearby galaxies shows that Population II is not confined to the nuclear regions alone. There is an all-pervading continuous background of Population II, and the spectacular Population I distribution, characteristic for the spiral arms and knots, is superposed upon this Population II background. It seems therefore that the stellar distributions for the region around our Sun, for the Cygnus star cloud and for the Carina star cloud, have all the characteristics of the observed distributions for spiral knots in nearby galaxies.

Some have argued that the division into Populations I and II is too sharp and that all sorts of gradations exist in nature. While this may be so, the Milky Way investigator can not help but be impressed with the frequency with which he encounters in his work sharp differences between the two Populations. The following examples, which were noted during the last few months of my stay in South Africa, serve to illustrate the point. They refer to two sections of our Milky Way system, one in the constellations of Sagittarius and Scorpio, *i.e.*, the section which marks the direction toward the center of our galaxy, the other in the constellations of Carina, Crux and Centaurus, where we find the strongest nearby concentration of stars, the direction in which we are probably looking along the spiral arm.

1. It has long been known that the direction toward the galactic center is heavily obscured. The nearby Ophiuchus complex of dark nebulae (within one thousand light years of the Sun) hides many of the more remote parts of the Milky Way system for the section in Sagittarius and Scorpio. But it has been recognized that the obscuration may not be too heavy for the section which marks the direction to the central star cloud. Baade has given what appears to be a reliable estimate of a total absorption of three magnitudes between our Sun (and the Earth) and the center itself. Photoelectric studies of faint O and B stars have recently been made at the Boyden Station by Van Wijk and myself and these show that two-thirds of the obscuration overlying the section of the galactic center occurs near the Sun, well within one quarter of the distance that separates us from the galactic center. A concentration of the O and B stars along with a concentration in the cosmic dust is characteristic for Population I and it is gratifying to note that, for the

direction of the center, Population I predominates only for the nearest parts.

2. Photographs made with the new Armagh-Dunsink-Harvard telescope of Baker-Schmidt design confirm the presence of a terrific abundance of faint and quite red stars toward the Sagittarius direction, whereas for the field in Carina (along the proposed spiral arm and at right angles to the direction toward the center) relatively blue stars continue to be the preponderant variety to fairly large distances. Again we find distributions of the Population I and II varieties as we expect them for our working-model of the galaxy.

3. Perhaps the most striking effect produced by our long exposure plates in blue and red light is that of the contrast in distribution of bright nebulosity for the Sagittarius and Carina sections of the Milky Way. All along the Carina-Crux-Centaurus section, bright nebulosities are observed in abundance, especially on photographs taken on red-sensitive emulsions which register the hydrogen Hα emission. There are a few known nearby reflection nebulosities for the Sagittarius and Scorpio section, but apart from these, little nebulosity is shown on the ADH plates for this section. The absence of faint emission nebulosities for the Sagittarius-Scorpio section is a most striking phenomenon; it offers further proof that Population II predominates for the Sagittarius-Scorpio section.

During the past ten years many new types of telescopes have been built which are devoted in part or completely to studies relating to the distant parts of our Milky Way system. New techniques of observation have been established and old ones have been improved to such an extent that they are also almost like new ones to the astronomer. One cannot single out a special type of telescope as offering the greatest promise of success in the study of the remote parts of the Milky Way. The greatest opportunity for advance lies in co-ordinated attempts by two or more telescopes each fitted with special auxiliary equipment and each executing the part for which it was designed.

There are now in operation six large Schmidt telescopes or modified Schmidts and it is no exaggeration to say that most of the observing time with these telescopes is devoted directly or indirectly to projects that will further our knowledge of the structure of our Milky Way system. The large fields of perfect optical definition of these telescopes render them very useful for comparative studies of stellar distribution over large regions of the sky. For research on the faintest stars, however, the Schmidt lacks in scale and for some of the richest fields the crowding of faint stars may become so great that the large Newtonian reflectors must be called in to assist. The Schmidts again are very useful for transferring an established standard sequence of magnitudes or colors from the center of a plate to any point within the large area of the sky covered by a single Schmidt photograph. But the first establish-

ment of the basic sequence cannot be done with greatest accuracy with the Schmidt-type telescopes, and here again one has to call on the large reflectors to assist, preferably on reflectors fitted with photoelectric equipment. At the moment the Schmidts seem to reign supreme in providing us with spectra of faint stars in the large numbers required for proper study of the distant parts of the Milky Way, but it would not be surprising if large reflectors fitted with slitless spectrographs were to come to the fore in this field within the next decade.

There is a newcomer among the Milky Way telescopes that bears watching: the "Radio Telescope." Still in its infancy, this new type of instrument has already begun to chart the Milky Way in wavelengths hitherto out of reach. We shall describe below some of the results already obtained with the radio telescopes, but no one who has watched their contributions during the past five years can doubt that they may well become the most powerful tools for exploring the depths of the Milky Way.

In this lecture, we should examine briefly a few specific research projects that provide important basic information regarding the distribution of stars, cosmic dust and gas at large distances from the Sun.

It has often been said that in modern warfare, in spite of wholly new weapons, the brunt of any attack continues to be carried by the old-fashioned combination of infantry and heavy artillery. So in Milky Way research, we must continue to depend on the combination spectra-magnitudes-colors for stars to the faintest limits within reach of our telescopes. The Schmidt-type telescopes provide us with spectra of stars to the 12th or 13th magnitude, and for these stars accurate magnitudes and colors, as needed, can be obtained with the aid of photoelectric photometry. In many cases the numbers of stars involved become, however, so great that it would be impracticable to measure the magnitudes and colors for all by photoelectric methods. With the aid of standard sequences of brightness and color, established for relatively few stars by photoelectric methods, the time-honored photographic and photored techniques can be used to provide accurate magnitudes and colors for thousands of faint stars. Present techniques enable us to penetrate nicely to distances of eight to ten thousand light years from the Sun, but not beyond, as long as we depend on the classical methods of spectral sorting in the regular photographic region of the spectrum.

Eight to ten thousand light years represents at first sight a very great distance, but it does not seem so big if we note that it represents only one-quarter to one-third the distance from our Sun to the galactic center. How are we to penetrate the remaining two-thirds of the distance to the galactic center? We shall see that we have not yet exhausted the possibilities of the objective prism and, further, that even without a large objective prism much useful work can be done through the use of star colors.

In our description of the use of the objective prism, we stressed so far only studies of the normal photographic part of the spectrum, *i.e.*, for wavelengths mostly between 3,500 and 5,000 Angstroms. New possibilities open up if we turn to greater wavelengths, especially to the spectral regions near 8,000 Angstroms, the near infra-red. At this wavelength, sensitive emulsions have now become available, notably the Eastman IN emulsion, which, properly sensitized, records very faint stars. The Warner and Swasey Observatory has been the pioneer in the field of infra-red spectral classification and has already contributed notably to our knowledge of the faint red stars and their distribution at great distances from the Sun. The newly-arrived 33-inch objective prism for the Armagh-Dunsink-Harvard telescope in South Africa will be used to photograph spectra of stars in southern Milky Way regions equally in the normal photographic and the infra-red region of the spectrum.

In spectral research, the normal red part of the spectrum should also not be ignored. The power of Hα surveys, which reveal the presence of fainter emission nebulae of the diffuse and planetary varieties, must not be underestimated. The Mount Wilson and Mount Palomar surveys (now supplemented with the southern Michigan survey) have demonstrated the value of this approach for smaller instruments and the splendid results obtained at the Mexican National Observatory at Tonanzintla have shown that all possibilities have by no means been exhausted.

We mentioned earlier in this lecture that in research on the structure of the Milky Way system we are concerned equally with stars and with the cosmic dust and gas in between the stars. Through color studies of stars reddened by the intervening cosmic dust, we learn much about particle sizes and optical characteristics of the tiny particles responsible for the observed scattering and absorption. During the past two years, a new item of information has been added relating to the degree of polarization and orientation of the plane of polarization of the light that has passed through a cloud of cosmic dust. For the present these polarization studies by Hall, Hiltner, and others are limited to the nearer parts of our galaxy, but they will most likely soon be extended to stars at great distances.

The distribution of cosmic dust requires our attention not only because of the intrinsic significance of knowledge regarding the distribution of cosmic dust in our galaxy, but also because the distribution of the dust affects the apparent stellar distribution. The analysis of straight starcounts, with or without references to star colors, is difficult under any circumstances, but without advance information on the amounts of galactic obscuration to be expected at various distances, the situation is almost hopeless—at least for most cosmic dust-ridden sections immediately in the band of the Milky Way. To obtain information about the distribution in depth of the cosmic dust, we turn to observations of the colors of distant variable stars, especially the Cepheid and

cluster-type variables. For the brighter of these it is now a relatively simple matter to obtain precision colors by photoelectric methods to distances of at least 15,000 light years from the Sun. The more distant variable stars of these types can not be observed with the aid of most existing photoelectric photometers, but, with expert handling, telescopes like the 82-inch at McDonald Observatory, the 100-inch at Mt. Wilson and the 200-inch at Mt. Palomar may be able to reach the stars to 30,000 light years from our Sun, at least in the more transparent directions. It should not be difficult to reach these same stars by photographic and photo-red techniques, the principal difficulty that we encounter here being that of establishing reliable standards of magnitude and color for the faint stars under consideration.

Radio entered the Milky Way field twenty years ago when Jansky of the Bell Telephone Laboratories first detected the presence of "radio noise" from the band of the Milky Way. He discovered that the strongest signal came from the direction of the galactic center. Others continued the work begun by Jansky, notably Reber, but it was not until toward the end of the war that the new science of Radio-Astronomy became a full-fledged scientific enterprise. Radio "Observatories"—institutes that devote their energies about equally to studies of the radiation from our Sun and from the Milky Way and beyond—are now in operation in many parts of the world. The leading observatory at the moment is probably that in Sidney, Australia, but, with Australia in the lead, Great Britain, Canada, the United States, and the Netherlands are not far behind.

This is not the occasion for a survey of recent advances in radio-astronomy of our galaxy, but we should discuss briefly how the new tool may be employed to penetrate to the far reaches of our Milky Way. We are then concerned with three groups of phenomena: (1) the Point-Sources of radio-emission, (2) the general galactic radio noise, and (3) the emission in the 21-cm band.

1. *Point-Sources.* The most surprising discovery of Radio-Astronomy has probably been that of Point-Sources of radio emission in the frequency range centered upon 100 Mc/sec. The strongest of these Point-Sources are in Cygnus and in Cassiopeia and their diameters are only 2′ and 6′, or possibly even smaller. Identification of the Point-Sources has not yet been possible, but it is worthy of note that the position of the Crab Nebula (a former Supernova and object of very high temperature) coincides with that of a Point-Source in Taurus. While the Point-Sources are probably, intrinsically, exceedingly energetic sources of radio-emission, it seems unlikely that the majority of those identified thus far are at distances in excess of 5,000 light years. There are a few more distant ones, but these are of extra-galactic origin and associated with large spirals.

2. *Galactic Radio-Emission.* General galactic radio-noise comes in

part from the farthest regions of our Milky Way (and outside), and it promises to contribute more than any other phenomenon to our knowledge of the general structure of our galaxy. The direction toward the galactic center is neatly marked in all sky-surveys and there is remarkable agreement on the direction to the center found by radio-methods (Bolton and Westfold, galactic longitude 325°, latitude —1°) and analyses based on observed stellar distributions or galactic rotation. In a way the most striking—and surprising—characteristic of galactic radio-noise is its rather mild concentration toward the central circle of the Milky Way. One would expect a much greater concentration than the observed one if Population I-like objects (O or B stars, interstellar gas, cosmic dust) were responsible for the observed radio-emission. In a recent survey of all available data, Westerhout and Oort came out in favor of an interpretation according to which the general galactic emission would originate from large numbers of radio stars, distributed in our galaxy in pretty much the same fashion as are the common dwarfs like our Sun.

3. *Emission in the 21-cm Band.* The most exciting recent discovery about radio-emission from our galaxy has been that of emission in the 21-cm band. Neutral hydrogen is the source of this emission. It had been known for some time that a reversal of the spin of an electron in the lowest energy level of the neutral hydrogen atom would produce an emission in the 21-cm band. Van de Hulst suggested that neutral hydrogen might be sufficiently plentiful in our galaxy for this rare occurrence to produce a perceptible amount of radio-emission. The radiation was detected first (March, 1951) by Purcell and Ewen at Harvard, whose discovery was confirmed and extended six weeks later by Muller and Oort at Kootwijk in Holland.

Most observations have been made with a fixed antenna or radio mirror and these show maxima whenever the Milky Way crosses the meridian. The widths of these maxima are so great that Oort and Muller concluded that the principal contributing gas clouds are only at one-thousand light years from our Sun. This does not necessarily mean that gas clouds at greater distances will not emit radiation in the 21-cm band, but their radiation will be absorbed by the nearby clouds before it has a chance to reach our receivers. Offhand it seems, therefore, that this new phenomenon will not make it possible to penetrate to great distances.

Oort has, however, suggested that there may be hope of penetrating to great distances if one can observe the radiation for clouds having widely different radial motions. The band-width of the emission is quite small and the radiation from a distant cloud of neutral hydrogen, with a radial motion relative to our Sun differing by 20 km/sec from that of an intervening nearby cloud, can probably pass unmolested through the nearby cloud. Because of the rotation of our galaxy this situation prevails for certain known directions along the band of the Milky Way

and for these the study of radiation in the 21-cm band may give useful information about what happens in the Milky Way at great distances from our Sun.

So ends our account of how we are in many different ways beginning to sound the "Depths of the Milky Way." No single instrument, no single technique offers the promise of a wide success. It is only through painstaking research all along the front that we shall be able to advance.

HARVARD COLLEGE OBSERVATORY.

Unique Attachments for Astronomical Telescopes*

By F. KEITH DALTON

As most amateur astronomers who enjoy observing the celestial bodies are usually very much interested in their eyepieces, diagonals, and other attachments for their telescopes, the writer is taking this opportunity to describe several unusual devices which he has designed and, with the assistance of good friends, has been able to build for his Alvan Clark 4-inch refractor, to add new advantages to this instrument in order to overcome some of the deficiencies found in standard fittings and to avoid the difficulties that spectators often experience in interpreting inverted or partially erected images. These new devices include simple graduated semi-circles for use in finding Venus and Mercury in daytime, a polarizing plate arranged to darken the north sky relative to Polaris for observation of the latter while the sun is shining, and erecting star and solar diagonals to give fully erect images while retaining the convenience of the diagonal feature, these being a considerable improvement over standard diagonals which erect the image on one axis only. All of these attachments are functioning very satisfactorily, fully justifying their design and the effort spent in constructing them.

FINDING VENUS AND MERCURY IN DAYTIME

The planet Venus is visible even in a small telescope at any time on a bright sunny day when it is above the horizon, provided it is not too close to the sun for safety to the eye in looking through the instrument, *i.e.*, not within three or four degrees from the sun. The problem is to find Venus. To do this by means of a graduated circle in right ascension and a clock mechanism, with a telescope which is portable and mounted on a tripod, entails a lot of adjustment each time it is set up

*Certain sections of this article are reprinted with permission from three shorter articles in the *Journal of the Royal Astronomical Society of Canada* in the issues of February, 1947, July, 1947, and January-February, 1948.

before the instrument is ready for use. A declination circle, graduated in degrees, is, of course, essential but does not present any difficulty.

As a simple means to locate Venus in right ascension, using the information given in the *Observer's Handbook of the Royal Astronomical Society,* the writer placed on the head of the tripod, in the equatorial plane and movable with the telescope, a semi-circular sun-dial with straight wire gnomon normal to the plane of the dial. This dial is graduated in hours and minutes, and the shadow of the gnomon always falls on, or very near to the 12 o'clock point when the telescope is pointed directly at the sun at any time of the day. To adjust in right ascension for Venus, one has only to turn the telescope so that the shadow of the gnomon falls on the time at which Venus is scheduled to transit the meridian, whether the planet be in east or west elongation. This gives the position of Venus in right ascension, except for the correction of the equation of time which from about April 1st until September 15th is never more than six and one half minutes, *i.e.,* 1.6 degrees, and may be neglected. At other times of the year, correction must be taken into account.

The finder of this Clark telescope has a field of five degrees in width; so with the declination properly set and with the shadow of the gnomon set to the time of transit of the planet, Venus will be found within the finder and is readily drawn to the centre of the cross wires and will appear in the main telescope.

This is a very simple but definitely consistent means of locating Venus whenever it is above the horizon, and can be used also to locate the planet, Mercury, earlier in the evening than by waiting until it appears in the western sky, *i.e.,* when this planet is in eastern elongations. It gives spectators quite a thrill to be shown Venus while the sun is shining,—the brighter the sun and more blue the sky the better it may be observed,—for they seem to think they are seeing the impossible,—a "star" in the sky in spite of the sunshine.

Locating Polaris at Noon

Blue skylight is definitely polarized in a circle in quadrature with the sun,—while the sun is shining above the horizon and for about one hour after it has set. This polarized region has a width of a few degrees and will include the North Star throughout the day at or near the time of the equinoxes.

By using a polarizing eyepiece, it then is possible to darken the sky and in this way to create a much greater contrast between Polaris and its background. This provides an improved condition for locating this star at noon if the sky be not cloudy, and will be most effective at the time of the equinoxes.

In this case, the equipment consists of a star diagonal with a Polaroid glass in front of the prism, thus analysing the light before it enters the eyepiece, which is very essential. The Polaroid is mounted in a cell which is turned to approximate position and inserted in the tube of the diag-

onal. It then is turned to best position by turning the diagonal. Placing the Polaroid plate in front of the glass prism is not only very convenient but is essential in order to obtain a uniformly darkened field.

This scheme is very effective and again provides a means of seeing a star while the sun is shining, especially good for the equinoxes, creating a thrill for spectators and quite a degree of satisfaction to the amateur observer who uses it.

Erecting Star Diagonals

When observing an object directly through an astronomical telescope, finder telescope or surveyor's transit, the image seen is usually inverted, as in a camera. By means of various further inverting devices, such as erector lenses, or the prism system in binoculars, the image can be re-inverted so as to appear erect. These devices all require the observer to look in the direction of the object being viewed and this often places him in a very inconvenient and cramped position when observing an object that is almost directly above him.

The usual star diagonal, with right-angle glass prism, undoubtedly was developed for the convenience and comfort of observers by using the reflecting feature to bring the rays out of the telescope at right angles to the optical axis of the instrument. Thus, in viewing an object near the zenith the observer looks in an approximately horizontal direction and, for objects in other parts of the sky, he looks downward from the horizontal, which usually is much more convenient and comfortable than placing one's eye below the telescope and looking upward through it. The ordinary star diagonal, however, has one disadvantage,—while it erects the image on one axis, *i.e.*, the vertical, it does not reverse it on the other axis, *i.e.*, the horizontal. Thus, the first quarter moon, though standing erect, will appear to bulge to the left rather than to the right, which frequently confuses the inexperienced spectator and leads to an inquiry as to why the moon has become turned around. With this condition he cannot readily compare the image he finds in the telescope with the moon as he ordinarily sees it.

The erecting star diagonals, Figures 1 and 2, with which the writer has been experimenting, have Amici roof prisms that combine a fully erecting system with the convenience of the star diagonal and retain all of the advantages of both. There is still a further advantage in that roof prisms can be used to turn the optical axis through an angle of 120°, Figure 2, or slightly more, whereas the triangular glass prism is limited quite close to 90°. This greater angle adds appreciably to the convenience of the observer in viewing objects in any part of the sky at altitudes higher than 30° above the horizon.

As the roof prism provides the erecting system, the spectator sees the moon, eclipses, etc., as he expects to see them; he is not confused by total or lateral inversion, and promptly proceeds to identify certain markings with which he is familiar. He is much better satisfied than if the

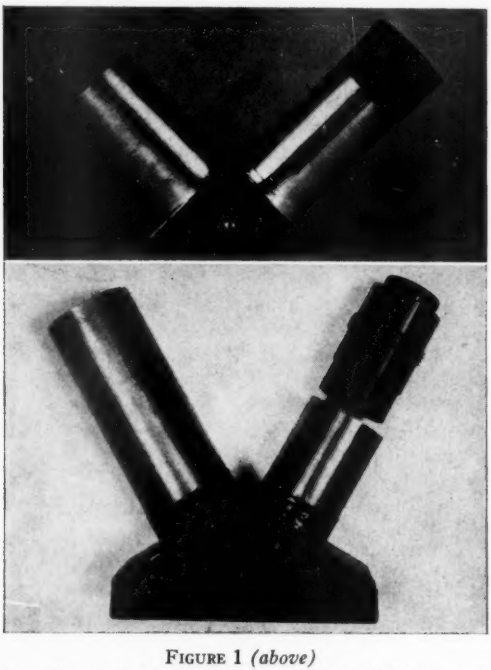


FIGURE 1 *(above)*
Erecting Star Diagonal, with 90-degree Amici Roof Prism, and the Eyepiece of the Navy 6 × 30 Binocular.

FIGURE 2 *(below)*
Erecting Star Diagonal, with 120-degree Amici Roof Prism, and the Eyepiece of the Navy 7 × 50 Binocular.

moon had some other orientation, and he enjoys the convenience of the diagonal feature.

The use of the erecting star diagonal introduces a problem in the matter of focussing range of the telescope, due to the path of light through the roof prism usually being longer than that through the ordinary right-angle prism. These erecting diagonals, therefore, must be placed nearer to the objective lens, or mirror, than is required with the usual star diagonal. The focussing range of the telescope may not be sufficient to take care of this or it may be necessary, for proper focus, to have the diagonal so close to the finder or other fittings that they interfere with the observer in preventing him from conveniently placing his eye at the eyepiece.

All standard eyepieces of the writer's Clark refractor telescope are of the Huygens type,—negative eyepieces, having the primary focus of the objective lens within the eyepiece cell. A solution to the problem of

focussing range, for low powers, appeared to be in the use of the Ramsden or Kellner positive eyepieces with the primary focus in front of the field lens. These would require that the diagonals be farther from the objective lens than when negative eyepieces were used. The writer, therefore, has obtained some positive eyepieces of low power,—the standard eyepieces of the 6 × 30 and 7 × 50 Navy binoculars, Figures 1 and 2, and of the Type BI Elevation telescope,—and has found these highly satisfactory, not only in solving the problem of focussing range but in width and flatness of field, and in sharpness of detail as well. These eyepieces give this telescope a magnification range of 55x to 82x. In both of the binocular eyepieces, the spacing between lenses has been reduced, below specified spacings, in order to minimize the optical interference of any dust particles which may collect on the front surface of the field lens, but the desired flatness of field in the eyepiece is still retained. These changes in spacing have been fully justified by the good results obtained.

For higher powers, 100x and above, using eyepieces of shorter focal length than for lower powers, there is not so much to be gained in focussing position by replacing negative eyepieces with the positive type in corresponding power and, for these higher magnifications, the focussing range of the writer's telescope is satisfactory with the negative eyepieces when the 90-degree roof prism, Figure 1, is used. The optical path through the 120-degree roof prism, Figure 2, however, is too long to permit its use in the higher magnification range, with either positive or negative eyepieces, keeping within the convenient focussing range of this telescope for celestial bodies. For these reasons, the writer has found it unnecessary to construct positive eyepieces for the higher powers.

These Amici roof prisms are similar to the triangular glass prisms in the ordinary star diagonals except that the reflecting face, *i.e.*, the hypotenuse in the right-angle prism, instead of being one flat surface consists of two flat faces at 90° to each other, resembling the double pitch roof of a building with a straight ridge. Each ray of light is reflected twice within the prism, the rays entering it on the left side being reflected over to the right side, and vice versa. This, with the vertical inversion as in the ordinary diagonal, gives the fully erect image in the telescope.

When the roof prism is used as a diagonal for a telescope, the ridge is not usually visible in the eyepiece. If, however, a positive eyepiece be of such very low power, *i.e.*, very long focal length, that the ridge, or some part of it, is at or near the position of the image being magnified by the eyepiece, the ridge may then be visible, either sharply or as a ghost, and be superimposed on the image. If this condition occur, the trouble may be remedied by drawing the eyepiece away from the prism —but not by moving it closer—and then refocussing the telescope. The writer has found a ghost image of the ridge in a negative eyepiece of low power but this disappears when the positive eyepieces are used.

The application of roof prisms, as erecting star diagonals, to an astronomical telescope provides a new and useful type of attachment with definite advantages and there does not appear to be any reason that they could not be used more generally. The astronomer and surveyor, of course, are familiar with inverted images and the partial inversion of the right-angle prism, and so are not confused by these inversions, but there still is much to be said in favour of the fully erect image combined with the convenience of the diagonal, especially for the spectator.

Diagonal Eyepieces for Finder Telescopes

The idea of the erecting star diagonal has been carried further in the development of the diagonal eyepiece for the finder which has proven to be a very desirable attachment when showing the wonders of the heavens to a queue of spectators. It is a great convenience in preventing the operator from interfering with the observers while keeping the instrument directed at the celestial bodies.

Two methods, using the ordinary right-angle prism, were first tried but neither of these was successful. When the prism was placed against the eyepiece, with the eye close to it, there was an area of very low partial reflection over a large part of the field. To have, on a finder, a complete star diagonal of the ordinary type results in a somewhat clumsy attachment which is very much in the way, and also reduces greatly both the magnification and the field of view.

The writer finally developed the diagonal eyepiece with a roof prism

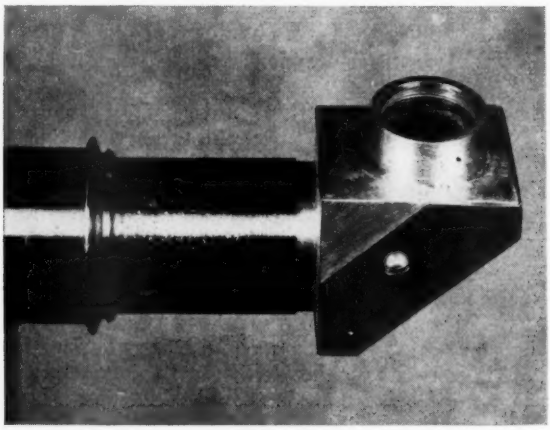


Figure 3

Thé Diagonal Eyepiece. This eyepiece, shown attached to the finder telescope, consists of field lens, Amici roof prism and eye lens, and may be turned to any desired position. It gives a fully erect image and the full field of view of the finder. Its compactness is of considerable advantage.

between the eye and field lenses—a neat compact device which is virtually streamlined to the finder telescope and is interchangeable with the ordinary eyepiece (Figure 3). This new eyepiece gives a fully erect image which has proven to be a very convenient feature, for the arrangement of stars seen now checks with that shown in the star map, not being inverted nor even turned over on one axis, and therefore is more easily identified than when the regular eyepiece is used. The full field of view of the finder is retained, and the magnifying power is only slightly reduced.

This is a positive eyepiece so it is adjusted in position to give a clear image of the cross-wires or reticule. It may be turned, on the axis of the finder, to any desired angle. From all points of view, this diagonal eyepiece is an extremely satisfactory device.

Erecting Solar Diagonals

The writer has also developed erecting diagonals for observing the sun and solar eclipses, which would have the same advantages in giving erect images, properly orientated, while retaining the convenience of the diagonal in viewing these objects when they are high in the sky. The problems, however, are quite different for the two types of diagonals. Whereas, in star diagonals, it is important that the rays of light enter and leave the prisms perpendicular to their first and last surfaces, respectively, and that they meet the reflecting surfaces internally at angles of incidence greater than 42 degrees, the critical angle of reflection, the solar diagonals do not include those requirements but involve a most interesting study in polarization of light by external reflection from the surfaces of transparent bodies.

One very important feature in telescopes for observing celestial bodies, other than our sun, is that they supply to the eyepiece as much light as possible so star diagonals take advantage of the total internal reflection of glass prisms. In viewing the sun, however, the reverse is essential, namely, that the sunlight be reduced to so low a value that the eye can not suffer permanent injury, nor even the discomfort of eye strain due to excessive brilliance. The necessary reduction of light may be obtained by various means or combinations of devices.

For directly viewing the sun through a telescope with an objective lens of three inches diameter, or less, a thin dark shade glass can give sufficient protection to the eye, but above this size of aperture protection should not depend entirely upon the shade glass for it may crack with the heat and cost the observer permanent blindness in at least a small area of the retina. There are other devices which are safe to use for direct solar observation through the larger telescopes, but if the sun be at a high altitude, these all require the observer to be in a cramped or otherwise uncomfortable position when placing his eye at the eyepiece.

Sir John Herschel devised a very satisfactory protective solar diagonal which is similar in appearance to an ordinary star diagonal but in which the right angle prism is replaced by one of small angle, ten de-

grees or less, and reflection takes place from the front or upper face which is accurately cut to flatness and placed at an angle of forty-five degrees to the optical axis of the telescope. Only five per cent of the sunlight is reflected to the eyepiece, nearly all of the light passing through the glass and on to the end of the mounting tube where the

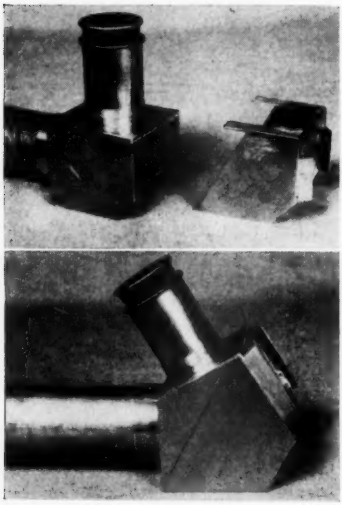


FIGURE 4

ERECTING SOLAR DIAGONALS

(a) The 90-degree diagonal, showing position of prisms in the mount, and the method of ventilating provided in the cover.

(b) The 120-degree diagonal, showing modification in shape and similar method of ventilation.

For either diagonal, light filters are placed on the eyepiece, as shown, or may be inside the tube which receives the eyepiece.

heat it creates may be freely radiated. The small part which passes through the eyepiece is still too much for the eye; so a shade glass must also be used. The reflecting element is in the form of a prism, rather than a block of glass with parallel faces, so that secondary reflections will be diverted and will not enter the eyepiece to produce ghost images.

This device, however, is a plane diagonal. The image seen is erect on one axis, *i.e.*, the vertical, but reversed on the other axis, *i.e.*, the horizontal. Thus, in a solar eclipse, the moon would appear to cross the sun from left to right, rather than in the correct direction, from right to left, and the rotation of the sun, as noted from successive observations, would appear to be reversed. The apparent shapes of sun-spots, too, are different due to this reversal.

With a view to developing a solar diagonal which would properly orientate the image, the writer has combined the necessary conditions of the erecting star diagonal with the protective light-reducing features of the Herschel solar diagonal to produce a new device, the erecting solar diagonal, shown in Figure 4. The reflecting element, Figure 5, consists of two roof prisms, of transparent glass, cemented together to produce a "V" groove for double external reflection, the two faces being accurately set at ninety degrees to each other. This element is

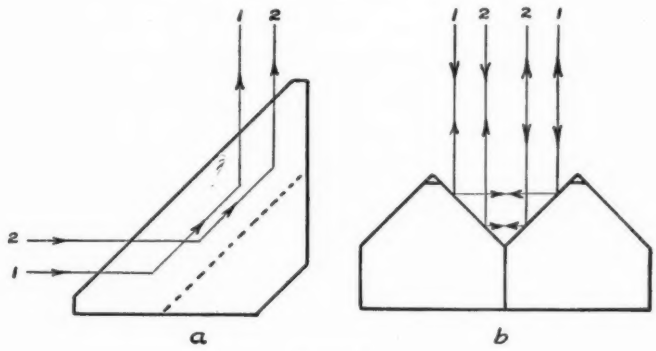


FIGURE 5

The reflecting element consisting of two roof prisms cemented together to form a "V" groove for double external reflection.

(a) Showing vertical inversion of rays in 90-degree diagonal.

(b) The "V" groove, and lateral inversion of rays.

so placed in the mount that the desired angle of deviation of the light beam is obtained.

Whereas, for total internal reflection in a star diagonal, the prism must be mounted so that the angle of deviation will be exactly the same as the apex angle of the prism, in solar diagonals any one reflecting element may be used for any angle of deviation from 0 to 180 degrees, its efficiency in reducing the light varying according to the angle of deviation chosen. These transparent prisms by-pass nearly all of the light, as in the Herschel solar diagonal, thus providing an excellent protective feature in this regard.

Each ray of light is reflected twice. After the first reflection, from either face, the ray crosses the groove and is reflected again from the second face, completing the deviation. Some rays cross the groove from left to right while others cross from right to left. For any given angle of deviation of the light beam and for rays parallel with the optical axis of the telescope,—and all rays considered are practically parallel,—the angle of incidence of the ray is the same at each face. The angle of reflection from each surface is, of course, equal to the angle of incidence at that surface, according to the simple law of reflection of light. After the second reflection, the rays enter the eyepiece.

The erecting solar diagonal is much more effective in reducing sunlight than the Herschel type of solar diagonal. The 90-degree Herschel diagonal reflects to the eyepiece 0.05, or five per cent of the sunlight whereas the erecting solar diagonal with the same angle of deviation reflects only 0.00206, or about one five hundredth part of the sunlight. Similarly, the 120-degree diagonal of the Herschel type reflects 0.0415 of the sunlight but the erecting solar diagonal reflects only 0.00289.

The striking differences in reflection factors are due to two reflections, the polarization of light in each and an effective optical rotation of the second reflecting surface in relation to the first. These great reductions, however, are not sufficient to eliminate the necessity of a shade glass in viewing the sun but this filter need not be as dark as the usual shade glass.

The writer has constructed two erecting solar diagonals, shown in Figure 4, with 90-degree and 120-degree angles of deviation, respectively. The 90-degree diagonal gives practically the maximum light reduction possible with this type of reflecting element, and is easy to construct with its simple cubical form. The 120-degree diagonal gives about forty per cent more light than the 90-degree diagonal and therefore requires a shade glass which is forty per cent darker. The greater angle of deviation is somewhat more convenient when viewing objects near the zenith.

For a shade glass, crossed polaroid glasses can be adjusted satisfactorily to give the desired reduction of light intensity, namely, with only four or five per cent of the density of the filters used with the Herschel solar diagonals. Two cautions, however, must be observed when polarized shade glasses are used. Firstly, the glasses must be so mounted and clamped that neither can rotate accidentally in relation to the other, or the intensity of light may suddenly increase, to the injury of the observer's eye. Also, particles of lint, or other fibrous dust between the polaroids may nullify, in small areas, the light-reducing properties of the combination and allow points of bright illumination on the retina of the eye, which, at least, would interfere with the observations. These risks may be obviated by placing the polarizing filter in front of the eyepiece, a feature which the writer has included in his designs of erecting solar diagonals. An unpolarized filter may, of course, be used safely on either side of the eyepiece.

In using Amici roof prisms, with several faces, for the reflecting element, care must be taken to suppress interference due to undesired secondary reflections from these faces. Any barriers should be placed between the prisms and the eyepiece where they will not heat as much as if they were in front of the prisms where they would receive the full heat from the sun's focussed rays.

The length of the optical path required for the erecting solar diagonal will be longer than for the Herschel type; so there is the same advantage as with erecting star diagonals in using positive eyepieces, rather than the negative type, to extend the focussing range of the telescope. As the erecting solar diagonals cause so great a reduction of the sunlight, the use of cemented lenses in the eyepieces should be quite satisfactory.

The mountings and covers for the erecting solar diagonals, shown in Figure 4, have been designed to protect the observer's face, hands and clothing from the concentrated beams of light and heat which pass through the prisms, and also to give necessary ventilation by means of

openings and louvres without allowing stray light, which may enter the mounting directly, to interfere with the image in the eyepiece. The metal of the mounting and cover is thicker than would be expected so as to conduct heat readily away from spots where it is concentrated.

The erecting solar diagonals, as shown and described here, give fully erect and properly orientated images combined with the convenience of the diagonal. The rotation of the sun on its axis and the passage of the moon across it during a solar eclipse are both given their correct respective directions, and sun-spots have their proper shape, not reversed horizontally as with the Herschel solar diagonal.

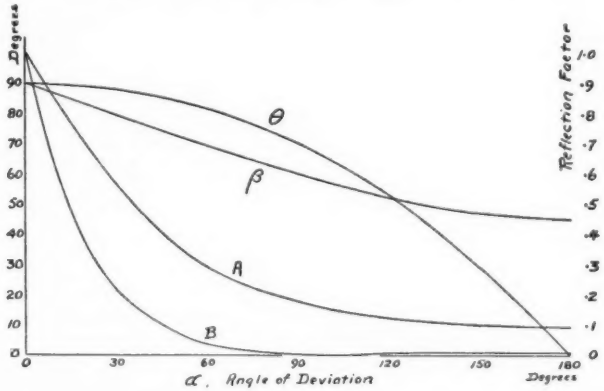


FIGURE 6

The relations of important angles and reflection factors: α, Overall angle of deviation of the light beam; β, Angle of incidence at the reflecting surfaces; θ, Effective angle of optical rotation of second reflecting surface in relation to the first surface; A, Reflection factor at the first surface for rays polarized in the plane of incidence and reflection; B, Reflection factor at the first surface for rays polarized in a plane perpendicular to the plane of incidence and reflection.

While, from the foregoing explanation, the behavior of light in the erecting solar diagonal may seem quite simple, it is, in reality, much more complex and as some readers may prefer a more technical explanation, the following information would then be of interest.

When light is reflected from the flat surface of a transparent body, the reflected rays are found to be vibrating in only two directions, at right angles to each other. They are said to be polarized—(A) in the plane of incidence, a plane containing the ray both before and after reflection, and (B) in a plane containing the ray but perpendicular to the plane of incidence. The reflection is only partial in either case, the reflection factors depending upon the angle of incidence of the light, which is related to the angle of deviation, α, and also being different for the two components, as shown in the graphs, A and B, Figure 6. The angle of incidence of the ray, at both surfaces, is shown by β in the graph.

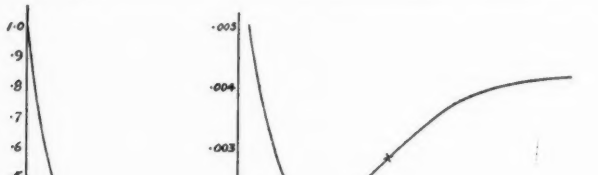


FIGURE 7

The overall reflection factor, showing the wide range in amount of reflected light for angles of deviation below 70 degrees, and the very small proportion of light which reaches the eyepiece for higher angles of deviation. The points for 90- and 120-degree diagonals are indicated.

As the ray passes from the first surface to the second, the second surface is in effect, rotated in relation to the first surface, through an angle, θ, less than 90 degrees, which also is related to the angle of deviation, Figure 6. The phenomenon therefore is complicated in that the components from the first reflection must be analysed, resolved into new components, A′ and B′, that are polarized in new planes related to the second surfaces, and then treated according to the reflection factors, A and B, for the respective new components.

The final reflected light then will be polarized. There will be two A′ components and two B′ components, one of each for the rays which cross the groove from left to right and one of each for rays which cross in the opposite direction. For the 90-degree diagonal and for higher angles of deviation, A′ components will be much larger than B′ components, in fact so large that the B′ components become practically negligible.

The effect of polarization is that the 90- and 120-degree erecting solar diagonals are much more effective in reducing the sunlight than could otherwise be expected by double reflection for the same average reflection at each surface. Whereas the 90-degree diagonal reflects to the eyepiece about 0.002 of the sunlight, without polarization the reflection would be 0.008. Similarly, while the 120-degree diagonal reflects 0.00289 of the sunlight, if there were not polarization and effective optical rotation of the second surface the value would be 0.00397.

The lowest overall reflection factor for this type of erecting solar diagonal, as calculated, is 0.0019, which occurs at an angle of deviation of approximately 96 degrees. This angle appears to be the same as the critical angle of deviation of an isosceles triangular prism when used

as a star diagonal, above which angle the prism ceases to give total internal reflection.

There is one pair of A′ and B′ components from each side of the "V" groove. The angle between the A′ components of each pair, at the eyepiece, will be θ, and that between the B′ components will be the same. For angles of deviation above 90 degrees, the B′ components are so small that they may be neglected.

The fact that the final reflected rays from the diagonal are polarized —in effect two equal components polarized in their respective planes of reflection from opposite faces of the "V" groove and separated by the angle θ—suggests that polarized shade glasses may be used. The first glass is placed so that its axis makes equal angles with both A′ components, to give the minimum transmission. The second glass is then rotated on the first glass to give the desired overall reduction of light. The formulae for the relations between important angles and reflection factors and calculated results for the range of possible angles of deviation will be found in the original article in the January-February, 1948, issue of the *Journal of the Royal Astronomical Society of Canada*.

Conclusion

All of the devices described in the preceding paragraphs have been constructed, and the writer has found them very convenient and fully satisfactory in performing their various functions. Venus has been located easily on bright sunny days and is much clearer than at later hours after the sun has set. Mercury can be found earlier in the evening than when visible to the unaided eye. Darkening of the north sky by polarization is quite effective. The finder diagonal eyepiece is very handy, indeed, and is a decided convenience. Finally, the erecting diagonals, both star and solar, are a great success and, with the binocular-type eyepieces, give exceptionally flat fields at all magnifying powers used.

The writer, therefore, can strongly recommend these devices to other amateur astronomers. The diagonals, however, are based upon the use of roof prisms which may not be easy to obtain, but a good supply may still be available. The method of locating Venus is of particular advantage for telescopes that are mounted on tripods.

The hobby of astronomy is very enjoyable but assisting the spectator is important, too, for he has demonstrated a deep interest in the heavens and all that he can see in them. To improve the instruments used in helping him to see and better to understand the celestial bodies is a worthwhile service which every amateur should be well prepared to render.

The Royal Astronomical Society of Canada, Toronto, Ontario.

The 250th Anniversary of the Berlin Observatory*

By JULIUS DICK

(Translated by Curt E. Friese, Carleton College)

All over the world there is probably only a small number of institutions dedicated to research in astronomy which can look back over a quarter millenium of uninterrupted history and fruitful learned activity. The Berlin Observatory, now located at Babelsberg, is one of them. Strangely enough, as a result of historical development, it has now again become part of that body of learned men with which it was associated at the time of its founding on July 11, 1700, the birthday of Frederick III, Elector of Brandenburg: originally the Society of Sciences and subsequently the German Academy of Sciences in Berlin.

This learned association owes its inception to the profound admiration and sincere friendship which linked the Electress Sophie Charlotte, a sensitive woman receptive to all matters in the realm of fine arts and learning, with Wilhelm Leibniz, her renowned preceptor and adviser. The ultimate and deepest reasons that may have guided this noble scion of the Guelphs, "the philosopher Charlotte of Prussia," in her plans and intentions can be discerned from the words spoken on her death-bed and revealed a few years later: "Do not mourn me, for I am now going to satisfy my curiosity about the primary causes of things which even my Leibniz has never been able to explain to me: Space, the Infinite, Existence and Non-Existence."

Charlotte's purely scientific aims coincided most happily with two far more secular desires of her consort, the Elector: his love for splendor and extravagant display and his desire, born out of his own vanity, to transform Berlin into an "Athens of the North," as Frederick II expressed it. On the other hand, there were also involved governmental considerations of quite a different nature, which arose from the practical care for his subjects and for the orderly conduct of his administration. However, in this connection we may quote Encke's introductory remarks to the first volume of the *Astronomische Beobachtungen auf der Königlichen Sternwarte zu Berlin:*

> "The first impetus for the foundation of an observatory in Berlin was given towards the end of the seventeenth century by the acceptance of the Gregorian Calendar by the Protestant Estates of Germany. King Frederick I (at that time still Elector Frederick

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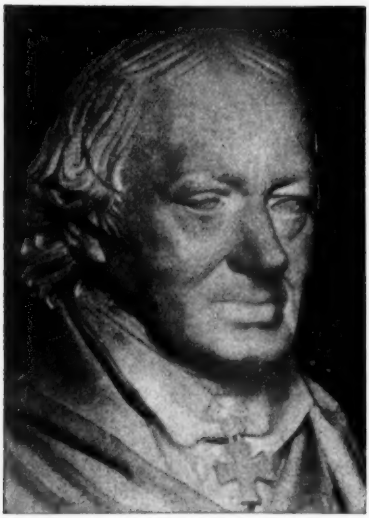
III) decided to found an observatory and a Society of Sciences, to coincide with this change which so deeply affected civilian life. The observatory was for the purpose of gaining independence of foreign research and investigations, in case similar events should take place in the future. Under the direction of the architect Grünberg, a rectangular tower of 5 stories, 84 feet high and 40 feet square, was erected in the Dorotheenstadt quarter of the city. The second floor was to be occupied by the Academy of Sciences for its meetings, while the astronomer of the society was to use the third floor for his observations. Slow progress was made in the construction of the building but it was eventually dedicated with proper ceremony on January 19, 1711."

As will be seen from the last sentence, the work of the now established observatory could not, to a large extent, begin immediately. The same was true of the society. Especially after his coronation as King Frederick I of Prussia on January 18, 1701, this spendthrift ruler needed so much money to satisfy his vanity and love for extravagant display in other fields that the scarcity of available funds prevented a speedy completion of the building intended to house the observatory and the society. Consequently, Gottfried Kirch, of Guben, who, at the age of 61, had been appointed astronomer of the society as early as May 18, 1700 (that is, even before the society was officially founded), and who was the foremost German astronomer of his time, did not live to see the dedication ceremony of the observatory in 1711 and never had a chance to observe the stars there. Gottfried Kirch died on July 25, 1710. He used for his observations the private observatory of Baron von Krosigk, Court Councillor, a wealthy lover of astronomy who had this observatory built in the Wallstrasse at Cölln, near the site now known as Spittelmarkt. Gottfried Kirch's successors also worked there on occasion.

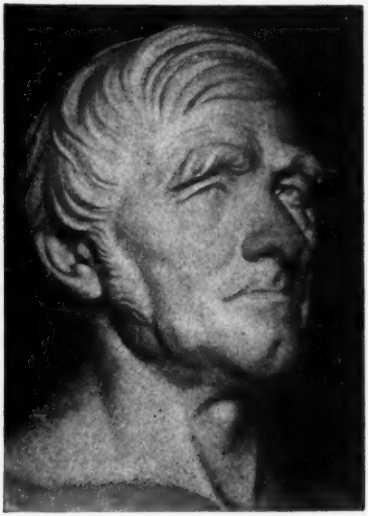
Financial support for the observatory and the society had already been meager and slow in coming under Frederick I, but it was withdrawn almost completely when after his death Frederick William I ascended the throne. His strict economy and lack of interest in arts and sciences did not serve to make either institution attractive or desirable, and so it is not surprising that after Gottfried Kirch's death the management of the Berlin Observatory should have changed frequently and rapidly. Indeed, there were hardly any scientists of rank and reputation at the head of the observatory during this period. A brief enumeration of their names and terms of office may suffice here: J. H. Hoffmann (1710-1716); Christfried Kirch, son of Gottfried Kirch (1716-1740); Wagner (1740-1745); and Grischon (1745-1749). Among these, Christfried Kirch deserves special mention as a devoted observer. He was ably assisted by his mother Margarethe and later by his sister Christine. After Grischon's death, the observatory was without a director. However, the fact should be mentioned that Lalande came there in 1752 for research work on the parallax of the moon, which Lacaille was carrying

GOTTFRIED KIRCH
1700-1710

CHRISTFRIED KIRCH
1716-1740



JOHANN ELERT BODE
1787-1825



JOHANN FRANZ ENCKE
1825-1863

out simultaneously at the Cape of Good Hope. This problem was then foremost in the minds of astronomers everywhere. No real change occurred when in 1754 Kies was appointed society astronomer, for he left Berlin the following year. The same is true of his successors, Aepinus (1755) and Huber (1756). A resumption of activities at the deserted observatory did not take place until the reign of Frederick II, who was extremely interested in the arts and sciences and who supplied the association (which in the meantime had been reorganized and renamed the Royal Academy of Sciences) with more funds, at which time Maupertuis was installed as its energetic president. In this connection, we might mention that Lambert also was a member of the Academy and was in charge of all construction work connected with it. Early in 1764, young Johann Bernoulli, a member of that Basle family which had produced so many scientists, was put in charge of the observatory at the recommendation of Maupertuis, and under his management the first valuable instrument was purchased in October, 1768: a large wall quadrant made by Bird, which even today fascinates visitors to Babelsberg as a splendid museum piece.

Johann Bernoulli III, who unfortunately was prevented by constant illness and subsequent deafness from the full use of his talent, is the first in the long roster of famous names which fortunately has continued without interruption until very recently and has so decisively influenced the character of the Berlin Observatory. At Lambert's request, and probably to assist the ailing Bernoulli, Johann Elert Bode of Hamburg was called to the Berlin Observatory on August 25, 1772, and was put in charge of the publication of an annual of astronomy. In this, the Academy returned to the idea mentioned above that had originally led to the foundation of the observatory. Accordingly, Bode published in 1774 the first volume of the *Berliner Astronomisches Jahrbuch*, with data for 1776. This annual has been published without interruption ever since, its latest volume, the one for 1951, having been made available to the public a few months ago. The last volume for which the Berlin Observatory was the responsible editor was that for 1883, published in 1881. Beginning with 1884, this responsibility was transferred to the Institute of Astronomical Computation, which had been separated from the observatory and founded expressly for this purpose in 1874. It may be mentioned now that this affiliated institution was located on the same premises as the observatory until 1912, when it was moved to a location of its own in Dahlem. However, in 1946 it was moved back to the site of the observatory in Babelsberg.

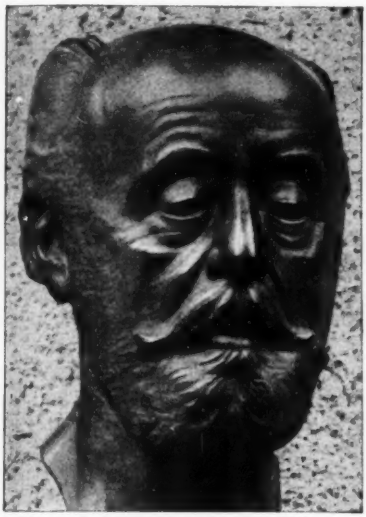
As publisher of the annual, which also contained a journal of observations and treatises on astronomy, and through observations of his own, Bode soon gained such a reputation that in 1787 he was put in charge of the observatory as successor to Bernoulli. The indefatigable and devoted work of this active man exhibited great and important results before he retired from his position at the head of the observatory

in 1825, after more than 50 years in office. He died a year later. In the reception hall at Babelsberg there is a marble bust of Bode fashioned by the masterly hand of Gottfried Schadow. Less valuable busts of Encke and Foerster were added later.

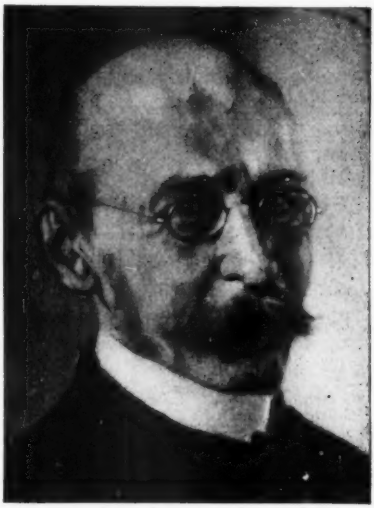
On October 11, 1825, Bode was succeeded by Johann Franz Encke, Gauss' most prominent student and one of the most famous astronomers of his time. No less a person than Bessel had recommended him for his position after he had made a name for himself through his research on the comet named after him and the determination of the parallax of the sun from the observations on the transit of Venus made in 1761.

A new era in the history of the Berlin Observatory begins with Encke. So much technical progress had been made in regard to the construction and installation of instruments and the methods of astronomical observation that the equipment of the Dorotheenstrasse observatory had become obsolete and could no longer meet the demands of scientific research, which had increased more and more as a result of the discoveries at the turn of the century, even though under Bode's direction some necessary structural changes had been made. When Encke began his term of office, he was promised that a new observatory would be built. However, this promise would not have been realized so soon if it had not been for Alexander von Humboldt, who in 1828 personally appealed to King Frederick William III for aid in the immediate construction of a new observatory, and the utilization of the experience gained by institutions outside Germany as well as the purchase of modern instruments. A site was chosen "just within the wall surrounding the city, very near the southern city limits," in order to keep the distance between the observatory and the Academy and university within reasonable bounds. "Encke Square" and "Bessel Street" are reminders of this old site. The corner stone was laid in 1832, and in 1835 construction was finished in accordance with Schinkel's design.

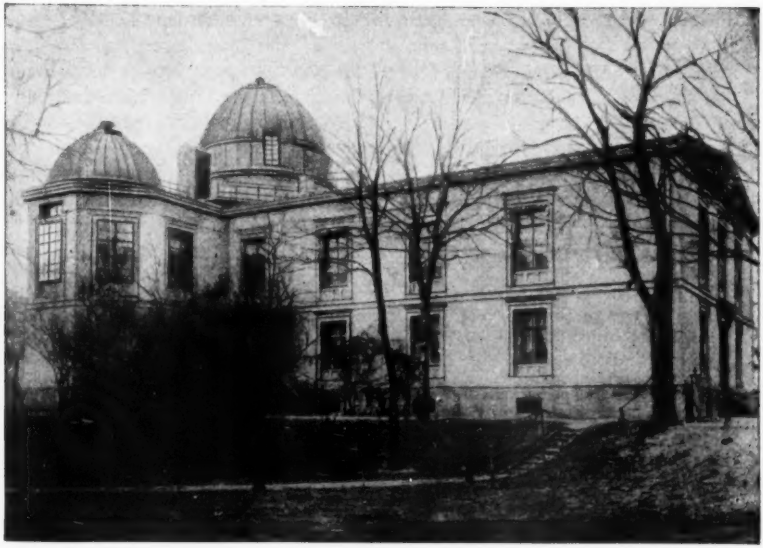
The main instrument of the new observatory was a 9-inch refractor with a focal distance of 4.4 meters built by Fraunhofer, a counterpart of the Dorpat refractor and thus exactly its equal in all dimensions, the last instrument fashioned by him. It was withdrawn in 1911 and given to the Optics Department of the German Museum at Munich. For the purposes of meridian-astronomy, a Pistor meridian circle with a 4-inch lens opening was purchased, together with a pendulum chronometer "Tiede 3," which has been in use at Babelsberg ever since. Furthermore, a heliometer built by Utzschneider and Fraunhofer was purchased. The following were added to the instruments that had been transferred from the old observatory: an instrument for the observation of sidereal passages by Dollond, a portable instrument of the same kind by Ertel, a comet finder by Utzschneider, several Dollond achromatic periscopes and a number of pendulum chronometers, all of which Encke was justified in calling a "splendid and complete stock of instruments." The observations and measurements which Encke and his assistants



WILHELM JULIUS FOERSTER
1865-1903



KARL HERMANN STRUVE
1904-1920



OBSERVATORY AT ENCKE SQUARE
1835-1913

made with the aid of these instruments were recorded in the first four volumes of *Astronomische Beobachtungen,* the first of a long series of major works to be published by the Berlin Observatory. The names of Encke's assistants should also be mentioned here in so far as they actually belonged to the observatory staff and were not merely temporary visitors: Johann Gottfried Galle, since 1851 in Breslau and renowned for his discovery of Neptune on September 23, 1846; Karl Theodor Robert Luther (at the Düsseldorf-Bilk Observatory from 1852); Franz Friedrich Ernst Brünnow (author of the famous text-book, who worked at Ann Arbor from 1854); Karl Christian Bruhns (in Leipzig from 1860); and Wilhelm Julius Foerster, who took office in 1855.

When in 1863 Encke was forced by a cerebral ailment to retire from the directorship of the observatory, Wilhelm Foerster succeeded him as acting head and, effective March, 1865, as official director. Simultaneously with his appointment the departmental position of the observatory, which so far had been part of the Academy of Sciences, was changed, the Royal Observatory being made an independent state institution in close connection with the university. Until his death on August 26, 1865, Encke officially remained both astronomer and member of the Academy. Thereafter, in 1866, upon the recommendation of Hansen, Arthur Auwers took over this office and was also appointed member of the Academy.

Foerster's collaborators at the time of his succession were Friedrich Tietjen, who in 1874 became an independent department head of the Institute of Astronomical Computation of the observatory, and Hermann Romberg, since 1873 at the Pulkova Observatory. Under Foerster's subsequent directorship the following astronomers were regular staff members of the observatory: Emil Hugo Becker (from 1883 to 1887 at Gotha, since 1887 in Strassburg), Viktor Knorre, Friedrich Küstner (in Bonn since 1891), and Hans Battermann (in Königsberg since 1904). During Foerster's time, too, a physical laboratory under the direction of Eugen Goldstein was added. A large number of guests and collaborators worked temporarily or as voluntary assistants at the observatory.

Foerster's success and merits were chiefly in the field of organized and co-operative scientific research and in the active support of institutions and corporations connected with it. In comparison to this, his own scientific work was less significant. Foerster was also constantly engaged in an effort to familiarize laymen with the achievements of astronomical research. Under his directorship, the publication of the *Berliner Astronomisches Jahrbuch,* which had hitherto been sponsored by the observatory, was in 1874 entrusted to the Institute of Astronomical Computation, founded that year and at first still part of the observatory under the directorship of Tietjen. A memorandum written by Foerster in 1871 was instrumental in the foundation of the Astro-Physical Observatory at Potsdam in spite of the initial objections of the Academy.

Foerster was one of the most active sponsors of the Astronomical Society established in Heidelberg in 1863; he also had an equal share in the foundation of the Reich Institute of Physics and Technology in 1886 and in the inauguration of the International Latitude Service in 1895. An examination of Foerster's efforts in behalf of sociology would go beyond the scope of this article. However, we must mention the foundation of the "Urania" Society of Berlin in 1888 and that of the association of friends of astronomy and astro-physical science in 1891. Max Wilhelm Meyer and Joseph Plassmann, whose co-operation Foerster secured, were scientists of high repute and yet able to communicate their knowledge to the layman.

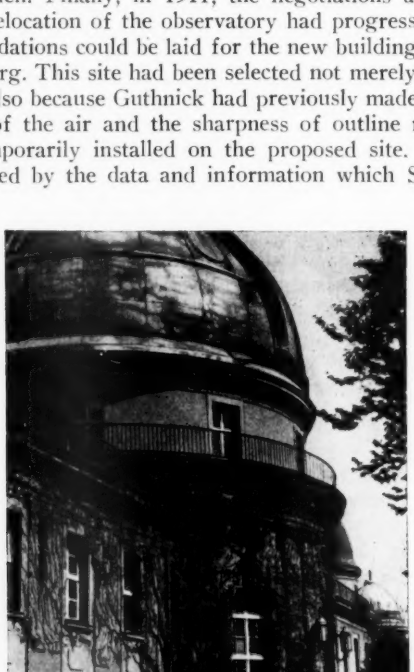
Within Foerster's time a second revolutionary discovery was made at the Berlin Observatory: Küstner's proof of the variation of the polar altitude. As a talented organizer, Forester continually tried to keep the instruments and equipment of the observatory up to date, giving his generous support to all research and experiments in this direction even at the risk of subsequent failure. In 1868, a new 8-inch meridian circle built by Pistor and Martins was purchased, which continues to prove its excellence at Babelsberg. All the great Babelsberg and Berlin meridian observation cycles were made with this instrument. In 1879, the so-called Universal Transit was constructed according to Foerster's design in the Bamberg workshop. This transit combines the functions of a universal instrument and one designed for the observation of sidereal passages, and Küstner with his great observational skill discovered with it the variation of the polar altitude.

At this point we may mention that after Tietjen's death in 1895 Julius Bauschinger was appointed his successor and the Institute of Astronomical Computation was separated from the observatory and made an independent organization. However, it continued to remain at the observatory.

A few weeks after his 70th birthday, in the spring of 1903, Foerster asked to be relieved of his duties as director of the Berlin Observatory. The increase in building activity near the observatory, the manifold difficulties in observation due to the dust and lights of the big city and the tremors caused by the heavy city traffic made a change of location imperative. At the same time, the new and different methods and aims of astronomical observation made a complete reorganization of the observatory necessary, a responsibility to be shouldered by a younger person. Wilhelm Foerster died at the age of 89 on January 18, 1921.

With these aims in mind, Karl Hermann Struve began his work as director of the Berlin Observatory on October 1, 1904. However, as is inevitable in such a project, much time was consumed by the difficulties connected with the scientific and educational aims and the financing of the institution before the move to Babelsberg could be realized. But this period of waiting, unwelcome though it was, was used to advantage in Berlin. After repeated attempts had been made, and failed, to modernize

the old 9-inch Fraunhofer refractor, a new and modern base built by Repsold was purchased for it in 1906, which was strong enough for larger and heavier lenses. For financial reasons it was not possible until 1911 to replace the 9-inch Fraunhofer lens by a 12-inch Zeiss lens, the old one and its base being donated to the German Museum at Munich, as mentioned above. With the improved instrument, and while the observatory was still in Berlin, Guthnick began in 1912 his preliminary work on the photometric measurement of stars, the effect of which may be regarded as important as the other two revolutionary discoveries made at the Berlin Observatory. Struve's collaborators during this period of transition were Leopold Courvoisier, since 1904, and Paul Guthnick, since 1906, both as official observers; and as assistants, in the order named, Joseph Hoelling, Friedrich Rahnenführer and Erwin Finlay-Freundlich. Finally, in 1911, the negotiations and preliminary work for the relocation of the observatory had progressed to the point where the foundations could be laid for the new building on the present site at Babelsberg. This site had been selected not merely for reasons of economy, but also because Guthnick had previously made careful checks of the purity of the air and the sharpness of outline recorded by an instrument temporarily installed on the proposed site. The new construction profited by the data and information which Struve had col-



Babelsberg Observatory
Since 1913

lected on an extensive trip through the United States where he visited the great observatories, and by a similar study carried out by Courvoisier at the Pulkova Observatory. In March, 1913, the work was largely finished, and it was possible to begin with the transfer of the instruments from the old observatory. This move was completed early in August, 1913. But only part of the new instruments that had been ordered had arrived when the first World War began, and it was only due to Struve's indefatigable efforts that even during the war all large instruments, with one exception, were actually delivered as ordered.

Hermann Struve has erected for himself a monument of more than passing importance in the construction and equipment of the Royal Observatory at Babelsberg (called the University Observatory of Babelsberg between 1918 and 1946). It is tragic indeed that although he witnessed the first years of its existence he was not destined to direct its subsequent development into a research institute covering all fields of modern astronomy. Hermann Struve died of the after-effects of a trolley accident on August 12, 1920. I may be excused here from listing in detail the complete equipment of the Babelsberg Observatory. The observations and measurements carried out with the instruments that were purchased and built when the observatory was moved from Berlin to Babelsberg, as well as the research performed during the two decades when Guthnick served as director of the observatory, enjoyed the generous support of the authorities and are well known to astronomers all over the world. It was no exaggeration to say that the Babelsberg Observatory had first-rate equipment satisfying the most exacting standards of modern astronomy. An indication of this can be seen in the fact that now, contrary to what had always been the custom in Berlin, no Babelsberg astronomer accepted a leading position elsewhere, even though many offers were made. The research opportunities afforded by this world-famous institute were such that other institutes at home and abroad, with few exceptions, were not attractive.

In accordance with the greatly extended scope of work at the new observatory, the staff was also increased, four observers and three assistants (four assistants from 1921 on) being employed. When Struve became director the posts of observers were held by Leopold Courvoisier, Paul Guthnick, Walther Zurhellen, and Julius Liebmann, while Erwin Finlay-Freundlich, Felicyan Kepinski and Richard Prager were assistants. Liebmann and Zurhellen were killed in action during World War I, and so, at the end of the war, the staff consisted of Courvoisier, Guthnick, Prager and Georg Otto Hermann, observers, and Herbert Fuss, Ernst Bernewitz and Kurt Felix Bottlinger, assistants.

When Guthnick became director on July 1, 1921, there began the last and most glorious period in the history of the Berlin Observatory, at least until the collapse of Germany, even if its inner structure was changed somewhat by political events after 1933. It was probably easy to finish construction of the building designed by Struve's foresight and

PAUL GUTHNICK
1921-1946

experience, a work which he had been unable to complete during the war years. However, Struve's interest was mainly along classical lines, and he would possibly not have provided the observatory with all the equipment indispensable to a modern institute trying to keep abreast of the rapid post-war development in the field of astronomy and to maintain the standards set by it: the accessory instruments, assorted apparatus and laboratory equipment for the evaluation and interpretation of the data and measurements obtained by the large instruments. Guthnick deserves permanent recognition because of his unceasing efforts towards this goal, his tireless observation and also his endeavor to make Babelsberg a place where not only the traditional work of astronomy but also astro-physical research was carried on in such a way that Babelsberg, to some extent the outpost of the Old World, could successfully compete with the giant observatories of the New World. Naturally, the generous sympathy and active support of the government agencies concerned were needed to reach this goal, and these were given amply and intelligently, while on the other hand Babelsberg expressed its gratitude by valuable contributions. Babelsberg was proud to welcome many scientists from foreign countries as guests every year, to work there temporarily or for extended periods of time. For the Babelsberg astronomers, the reputation of the institute meant honor, while the large number of astronomers who graduated from Babelsberg felt a special obligation towards the institute.

It was a particularly happy event when in 1931 Babelsberg received a valuable addition by the incorporation of the observatory located on Mount Erbisbühl, near Sonneberg, which was under the direction of Hoffmeister. The observatory thus obtained a mountain outpost which was able to render valuable assistance particularly by collateral work in the field of photography.

When Guthnick took over the office of director, the staff consisted of Courvoisier, senior observer; Prager, Struve and Bottlinger, observers; and Fuss, Bernewitz and Friedrich Wilhelm Herbert Pavel, assistants. Changes occurred in the course of the years when the position of a fourth assistant was added; some staff members left and others died, so that until 1945 the records show the following names of full-time staff members: Alfred Brill, Margarethe Güssow, Friedrich Ludwig Cuno Hoffmeister (at Sonneberg), Heribert Schneller, Nicolaus Benjamin Richter, Ludwig Biermann, Joachim Otto Stobbe, Otto Hachenberg, Heinrich van Schewich (at Sonneberg), Peter Wellmann and this writer.

The second World War and the post-war years have wrought considerable changes in the observatory and have severely damaged its external and internal structures. It is the responsibility of the German Academy of Sciences in Berlin to aid in the reconstruction and repair the damage done, since the observatory was again placed under the care of the Academy on January 1, 1947, as an independent research institute and no longer served the educational purposes of the university.

When Guthnick, after having been retired, died on September 9, 1947, a devoted research scientist had passed away.

I may be excused at this point for bringing this chronicle to a close, since, particularly in the last chapter, my purpose was to record the relatively unknown history of the personnel of the Berlin Observatory during its history of two and a half centuries, rather than to give an account of its instruments and equipment, which are well known and about which information can readily be obtained elsewhere. I hope that I have succeeded in communicating to my readers the impression that in the two and a half centuries of its existence the Berlin Observatory has done justice to the motto which Leibniz, possibly with a view to the joint creation of both the Observatory and the Academy, bestowed upon the Academy on the occasion of its inauguration:

Cognata ad sidera tendit.

Contributions of the Meteoritical Society

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles 24

The Determination of the Co-ordinates of a Meteor by Orthographic Projection*

PAUL E. WYLIE
Department of Astronomy, University of California, Los Angeles 24

ABSTRACT

A graphical method of solving the *PZM* or astronomical triangle is presented —one adapted particularly to observations of meteors.

Most problems in spherical astronomy involve precise observations followed by computations utilizing trigonometric tables of 5, 6, or 7 places. Observations of meteors, however, are usually surprise events, and, in consequence, the time, altitude, and azimuth of the phenomenon can be determined only roughly. An approximate graphical method of solving the *PZM* triangle conforms to the precision of the data, expedites the solution, and serves to eliminate the drudgery of numerical computation.

The method of this paper utilizes an orthographic projection of the various circles of the celestial sphere on the plane of the observer's meridian. It is assumed that the longitude, latitude, and standard time at the place of observation are known and that the azimuth (or bearing) and altitude of the meteor have been observed. It is desired to determine the right ascension and declination of the meteor. An example will clarify the method.

On 1951 April 30, at $21^h\,30^m$ P.S.T., in longitude W. 123°.5, latitude N. 34°.1, a meteor was observed bearing N. 60° W., at an altitude of 39° ; required, the right ascension and declination of the meteor.

First (*cf.* Fig. 1), draw a complete circle of any convenient size. This circle represents the observer's meridian. A horizontal diameter, *NOS*, is the projection of the plane of the observer's horizon on the plane of the meridian. From this horizon lay off with a protractor the angle NOP_n, equal to the observer's latitude (in this case, N. 34°.1). P_nOP_s then represents the polar axis of the sphere. Draw QOQ' perpendicular to P_nOP_s. This is the projection, on the meridian, of the celestial equator. Draw the line *OZ* to represent the vertical, perpendicular to *NOS*, *Z* being the zenith. Now we are ready to apply our observational data. From *NOS*, with center at *O*, lay off an angle (39°) equal to the alti-

*Read at the 14th Meeting of the Society, Los Angeles, California, 1951 June 18-19.

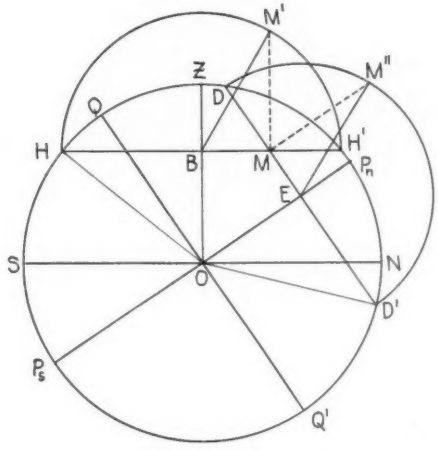


FIG. 1

tude of the meteor, and, where this line intersects the meridian (at H or H'), draw the line HBH', parallel to NOS; this is the projection of the meteor's almucantar or parallel of altitude. In order to lay off the bearing of the meteor, we must first rotate the almucantar about the diameter HH' into the plane of the meridian. This rotation is performed conventionally, according to the usual methods of descriptive geometry; that is, if the meteor is on the *far* side of the sphere (as it is, in this case), then that half of the almucantar that contains the meteor is turned *up*. The opposite convention applies, of course, if the meteor is on the *near* side of the sphere. So, with radius HB or $H'B$ and center at B, we describe the semicircle centered at B. Now we are looking down onto the almucantar. The bearing of the meteor (60° W.) is laid off as the angle $M'BH'$ from the north point H'. M' represents the meteor. Next, turn the almucantar back to its original position. M' will project, perpendicularly to HH', to the point M, on the plane of the meridian. A line thru M, parallel to the equator QQ', will be the projection of the meteor's parallel of declination—the line DED' in the figure. The arc of the meridian between Q' and D', or the angle $Q'OD'$, is the meteor's declination. This angle, as measured with the protractor, is $+42°$.

It remains to discover the meteor's hour-angle. To find this, we rotate the declination circle DED' into the plane of the meridian by drawing the semicircle with center at E and radius ED (or ED'). When this construction is done, M will project, perpendicularly to DD', to M''. Then the arc DM'' (or the angle DEM'') is the hour-angle of the meteor. This quantity also is measured with the protractor; it is found to be 66° or $4^h\,24^m$ west.

This last step concludes the solution of the graphical problem. The right ascension of the meteor is found in the ordinary way by means of the fundamental relation, local sidereal time minus the local hour-angle of the meteor equals the right ascension of the meteor ($\alpha = \theta - t$). These steps need not be detailed here. It is in order, however, to suggest that *The American Nautical Almanac* be used instead of *The American Ephemeris and Nautical Almanac,* since the former, in the guise of GHA ♈, makes the Greenwich sidereal time almost directly available.

The method just outlined, when once it is understood, requires only a few minutes for a solution, and it should yield coördinates accurate to about $\pm$ ½°. It is an ancient method; it can be traced back to Ptolemy[1] (A.D. 100-170), and it may be rooted in the lost trigonometric work of Hipparchus (180-110 B.C.); it suffices to solve any spherical triangle that may, alternatively, be solved trigonometrically; it is a quick, easily visualized, approximate method, worthy of more extensive use than it is given today, both in practice and in teaching.

REFERENCE

[1] *V.* O. Neugebauer, "History of Ancient Astronomy," *Publ. Astron. Soc. Pacific,* **58**, 107-8, 1946.

New Tektite Areas in Texas

The following abstract of a paper on "New Tektite Areas in Texas," by Virgil E. Barnes, Bureau of Economic Geology, University of Texas, Austin, appears on p. 14 of the program of the 1951 annual meetings of the Geological Society of America and allied societies, held in Detroit, Michigan, November 8-10, 1951:

"Tektites have been collected for many years by the residents around Muldoon, Fayette County, in a 5- by 10-mile area. Recently 2 tektites have been found in Gonzales County. The glass of some of the tektites (rough specimens) is light olive-brown (5Y 5/6) and highly translucent, whereas that of the bediasites (Barnes, *Univ. Texas Publ. 3945,* pp. 477-656, 1940) is only feebly translucent on thin edges. The refractive index of the glass (3 specimens) is 1.489 ± 0.003, which is the average of the refractive index of moldavites. Some of the Muldoon tektites resemble moldavites more closely than they do any other tektite group. The distribution of tektites in Texas suggests that they are weathering out of the upper part of the Upper Eocene Jackson formation.

"The chemical composition of tektites and the presence of included lechatelerite particles suggested to Barnes that tektites are fused sediments and therefore of terrestrial origin. However, the two periods of fusion exhibited by australites were recognized as being incompatible with a terrestrial origin. It is now suggested that tektites are derived from a celestial body, destroyed by collision, which contained sedimentary and other rocks similar to those on Earth. Glasses formed from

such a body would have a wide range in composition and could include supposedly nontektite glasses, such as Libyan Desert glass, and questioned tektite glasses, such as the americanites."

Streamlining of the Carolina Bays

The following abstract entitled "Streamlining of the Carolina Bays," by H. E. LeGrand, Box 2719, U. S. Geological Survey, Raleigh, North Carolina, appears on p. 51, *loc. cit.* in the next preceding note:

"Ground-water studies in the area of the Carolina Bays have revealed a singularly consistent set of subsurface conditions when considered collectively. These conditions, apparently related to the origin of the Bays, are (1) the presence of distinctly bedded clays in which at least one bed of limestone occurs, generally less than 25 feet thick and less than 150 feet beneath the surface; (2) a remarkably simple monoclinal structure, especially in the uppermost beds, ideally suited for artesian conditions; (3) solution under artesian rather than water-table conditions in the near-surface bed of limestone, resulting in slow but regular removal of mineral constituents during long periods since deposition of the soluble beds.

"This hypothesis supposes that solution in a near-surface artesian aquifer composed of limestone resulted in subsidence of overlying clay into this aquifer; thus, a normal sink was formed. This condition was followed by streamline ground-water flow around this impermeable clay obstruction. This caused increased circulation on the down-gradient side of the obstruction, leading to increased solution and subsidence in that area. The slow, continuous movement of ground water as streamline flow around the impermeable clay shaped the dissolved area into an ellipsoid, or, more generally, into an ovoid, the more pointed end of which is down-gradient.

"The hypothesis of streamline origin apparently accounts for genetic features of the Bays. Sand rims which characterize parts of some Bays are considered as extraneous and as not requiring explanation under this hypothesis."

The results of this investigation seem strongly to support the "hypothesis of complex origin" (or the "artesian-solution-lacustrine-aeolian hypothesis") of the late Douglas Johnson and so completely to refute the meteoritic hypothesis of the origin of the Bays.

President of the Society: L. F. Brady, 922½ Forest Avenue, Tempe, Arizona
Secretary of the Society: John A. Russell, Department of Astronomy, University of Southern California, Los Angeles 7, California

The Planets in January, 1952

By RAYMOND H. WILSON, JR.

NOTE: The time employed is Central Standard Time, unless otherwise indicated. The phenomena have been chosen and described for the North American continent, and especially for the United States. The basic data have been taken principally from the *American Ephemeris and Nautical Almanac*.

Sun. The sun will be slowly gaining headway northward again, so that at the end of the month it will be less than 18 degrees south of the equator. The earth will pass its annual perihelion point, where it is closest to the sun, on January 4.

Moon. The phases of the moon will occur as follows:

First Quarter	January	3	11 P.M.
Full Moon		11	11 P.M.
Last Quarter		20	1 A.M.
New Moon		26	4 P.M.

The moon will be at its monthly perigee point, where it is closest to the earth, on January 26.

Evening and Morning Stars. Jupiter will be visible in the early evening, Saturn and Mars after midnight, and Venus in the eastern dawn.

Mercury. This difficult planet will stand 23 degrees west of the sun on January 6. Hence it might be seen low in the southeastern dawn during the first half of the month.

Venus. After its rising at about 5 A.M., Venus will be conspicuous, low in the southeast.

Mars. Mars, moving rapidly southeastward, will be rising some half hour after Saturn at about 1:30 A.M. The two planets will be almost equally bright, but Mars is always the redder. On January 2, there will be a notable conjunction with Neptune, which is described under the latter planet.

Jupiter. On the meridian at sunset, Jupiter will be the brightest object in the early evening sky.

Saturn. Saturn will be near the meridian, about 10 degrees northwest of Mars, just before dawn.

Uranus. Uranus will be moving slowly west-northwestward at about midway between ϵ and ζ Geminorum. It will stand in opposition to the sun on January 3.

Neptune. Neptune will be almost stationary at a point 4 degrees north of Spica. The planet should be easy to find on the morning of January 2, when it will be only *10 minutes of arc* south of Mars.

Department of Mathematics, University of Louisville, Kentucky.
November 2, 1951.

Occultation Predictions for January, 1952

(Taken from the *American Ephemeris*)

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Occultations Visible in Longitude +72° 30′, Latitude +42° 30′

1952 Date	Star	Mag.	Ph	Greenwich C.T.	*a*	*b*	Angle E from N
Jan. 2	BD—0°4566	7.4	I	24 6.1	—1.1	+0.5	49
3	21 Pisc	5.8	I	2 3.1	—0.5	+0.3	42
4	BD+11°172	7.0	I	23 30.4	—1.4	+1.5	45
5	20H¹.Arie	6.4	I	22 14.6	—2.9	—0.3	112
6	BD+17°339	7.4	I	4 10.3	—0.9	—0.9	77
7	161 B.Arie	7.0	I	7 27.2	—0.2	—0.2	50
7	BD+24°583	6.9	I	22 30.4	+0.1	+3.3	22
7	BD+24°587	6.8	I	22 47.0	—0.5	+2.6	40
10	136 Taur	4.5	I	6 50.3	—0.9	—1.8	108
13	η Canc	5.5	E	10 24.9	—0.6	—1.5	272
15	ν Leon	5.2	E	4 42.7	—1.7	+0.8	278
16	37 Sext	6.3	E	7 48.5	—2.2	—0.5	283

Occultations Visible in Longitude +91° 0′, Latitude +40° 0′

Jan. 2	BD—0°4566	7.4	I	23 44.2	—0.9	+1.7	26
3	21 Pisc	5.8	I	1 49.4	—0.8	+1.1	32
6	BD+17°339	7.4	I	3 48.7	—1.8	—0.9	85
7	161 B.Arie	7.0	I	7 22.6	—0.5	—1.0	78
10	136 Taur	4.5	I	6 38.1	—1.1	—3.3	140
15	ν Leon	5.2	E	4 14.0	—0.9	+2.1	259
17	υ Leon	4.5	I	12 32.9	+0.1	—3.2	183

Occultations Visible in Longitude +98° 0′, Latitude +31° 0′

Jan. 3	21 Pisc	5.8	I	1 33.4	—1.4	+0.9	50
6	BD+17°339	7.4	I	3 49.4	—	—	121
7	161 B.Arie	7.0	I	7 33.4	—0.2	—2.2	117
9	38 B.Auri	6.5	I	9 53.9	—1.8	+1.8	32
30	12 Pisc	7.1	I	2 13.7	0.0	+2.8	2

Occultations Visible in Longitude +120° 0′, Latitude +36° 0′

Jan. 1	ϵ Aqar	5.4	I	3 2.5	+0.2	+1.9	9
2	BD—5°5917	6.6	I	3 57.4	0.0	+2.0	9
3	21 Pisc	5.8	I	1 31.4	—	—	339
6	BD+17°339	7.4	I	2 46.6	—2.0	+1.4	62
7	161 B.Arie	7.0	I	7 3.1	—1.6	—2.5	113
9	38 B.Auri	6.5	I	9 21.7	—1.8	+0.2	59
29	167 G.Aqar m	6.4	I	2 19.5	+0.6	+3.3	354
30	13 Pisc	6.5	I	2 43.6	—0.7	+0.1	55

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

These notes consist of the solutions of two fireballs which have recently been completed. However, for every one for which enough data are reported to make computation possible, dozens are in our files with reports from only one observer. It is one of our difficult problems to induce more persons, capable of making satisfactory observations, to do so and send them in. We particularly urge amateur astronomical societies to call the importance of such reports to their members. We even venture to request better co-operation on the part of more professional astronomers and of more officers of ships, both merchant and naval. The time required to send such a report is very small and the benefit to science often is very considerable. I sincerely hope that all who read this request will make some effort to comply.

The Oregon Fireball of 1945 July 1

A.M.S. No. 2324

The fireball appeared at about 9:18 P.S.T. on the above date, with a path roughly from N.W. towards S.E. over western Oregon. As usual, the reports were gathered and sent to me by Professor J. Hugh Pruett of the University of Oregon, but the object was not observed as widely as is usual in that state, and the first study of the reports led me to think no solution could be derived. Recently, however, as the object left a long-enduring train, another attempt was made and some sort of a solution obtained. Though I do not have great confidence in the exactness of the derived data, they suffice, I believe, to give at least approximate heights and direction of drift and, more roughly, the radiant. This latter had an orbit calculated largely to find the inclination, which turned out to be low. The motion was direct. The elements π and Ω may be very rough indeed.

The key reports were by F. P. Quick at Applegate, Oregon (S3), and a joint report by Earl Hammond and O. R. Helm at Bray, California (S1). From Eugene, Oregon, came several reports giving azimuths, one by Mrs. Ferne Thompson (S5) stating that it started a little to the left of Jupiter. R. G. Voude, Willits, California (S1), gave a_2 and h_2 and direction of motion. Azimuths also were given from Tangent, Oregon (S19), Cottage Grove, Oregon (S18), and Albany, Oregon (S16), and notes on motion from Bend, Oregon (S20). Curiously, all these stations except S1 and S20 are nearly along longitude 123° west. This fact complicated the solution. Nothing could be done without the reports from S1 and S3, yet their beginning azimuths did not cut one another. To use them I had to assume S1 used magnetic west, not *true* west. There is an excellent diagram from this station showing the altitudes and slope of the path. These and the differences in azimuth remain unchanged. To use the azimuth of S3, I had to assume that the observer had used the magnetic correction to true north with the wrong sign. He was positive all the path was north of him.

With these two rather extreme assumptions, all the other data fall into unexpectedly good accord, for both beginning and end heights, and the path fits in well with the general notes given by the other observers. The usual data follow in tabular form:

A.M.S. No. 2324

Date	1945 July 1:72 G.M.T.; July 2:22 U.T.
Sidereal time at end point	221°.2
Began over	λ 124° 30′ w; ϕ 43° 12′ N at 101 ± 4 km (3 observers)
Ended over	λ 123° 08′ w; ϕ 42° 35′ N at 17 ± 7 km (4 observers)
Length of path	153 km
Projected length of path	127 km
Radiant (uncorrected)	a = 121°, h = 34°
Zenith correction (parabolic)	5°
Radiant (corrected)	a = 121°, h = 29°; α = 135°, δ = +41°
Orbit	
ι	12°
Ω	100°
π	232°
q	0.05 AU

The fireball was seen in early twilight but was quite brilliant. Estimates of duration are lacking. S2 states that it burst 2° above northern horizon. All estimates of end altitudes are complicated because of the mountains in this part of Oregon. Notes on the train are now quoted: S1, ". . . it left a smoke trail the whole length of its path, which remained visible in the fading sunlight for more than ten minutes" (letter July 5). Second letter (August 1): ". . . the smoke trail did not seem to drift much but dissipated gradually—if any drift, I would say south. There seemed to be quite a good-sized path of smoke at the beginning and it narrowed as it neared the earth, somewhat wavy." S3, ". . . a thin white smoke trail which soon became fluffy broke up and if I remember right it drifted upwards. I guess it lasted about three minutes" (from card of August 6). ". . . there was a long trail of white smoke which soon became fluffy, but I don't think it lasted ten minutes. I would say about three minutes" (letter of July 30). An upward drift for S3 is wholly consistent with a drift to the south as seen from S1. Therefore, we may rather confidently conclude that the drift was to the south. The Sun was only a few degrees below the horigon, as tested on a large celestial globe, so the train was apparently wholly or partly in direct sunlight. That the other observers report no train is probably due to their relative positions, or, in same cases, to distance. As S1 definitely says the train was left over "the whole length of its path," we have another case of a smoke train, so-called, reaching into the zone of the night trains, which latter is roughly between 75 and 110 km height. Obviously nothing can be deduced about the velocity of the drift.

We are greatly indebted to all the observers, especially those who sent second letters, and most of all to Professor Pruett for efficiently carrying out his duties as regional director, thus making this solution possible. Limitations of space forbid giving the names of all observers and their reports in full.

The Massachusetts Fireball of 1950 September 4

A.M.S. No. 2325

On this date at about 8:54 P.M., E.S.T., a fine fireball appeared over Massachusetts and moving in a roughly N.E. direction ended over Cape Cod Bay. Several reports eventually reached me: one by Miss Sarah L. Lippencott then at Maria Mitchell Observatory, S1; one from William K. Davis of Longmeadow, Massachusetts, S2, along with some incomplete ones he collected from persons in his area; and two kindly loaned me by Harvard College Observatory. One of these by John Patterson of Newton Center, S8, along with that from S1 are the key reports. The other was from Lillian Rogers of Hyde Park, Massachusetts, S7, and was

in general corroborative of that from S8. S1 gave: α_2 14h 45m, δ_1 +60°, α_2 11h 25m, δ_2 +68°, maximum brightness at α 12h 50m, δ +67°.5, duration 5 seconds, white, several times brighter than Venus. S8 sent in an excellent sketch with his report showing γ, α, β Aquilae very near the beginning point, and Jupiter in relation to the end and explosion points, both of which lay near. From a large celestial globe I deduced for S8: a_1 1°, h_1 50°, a_2 311°, h_2 24°, for explosion point a 321°, h 31°; color blue-green, slow, slight curvature of path. The usable data from S2 are: a_1 281°, color blue-green, 3 seconds, twice the brightness of Venus. The other reports are in general terms and exact co-ordinates cannot be deduced from them. The solution depends upon the above, partly confirmed by the general statements of the others.

As usual a map of the region was prepared using a scale of $2^{mm} = 1'$ in latitude, and S1, S2 and S8 were entered thereon. It was at once obvious that, from the excellent map of S8 and the reports of S2 and two others near S2 which though not in exact terms yet corroborated his azimuth, that the fireball could not have been noted at S1 until it had traveled part of its path. In other words α_1 and δ_1 for S1 refer to a point on the path and not to the actual beginning. Fortunately, the altitudes of explosion point and of end point were practically equal as seen from S1 and S8. However, their azimuths cut so close to S1 that a solution based, as usual, upon these intersections would obviously be erroneous. So I chose two points on a straight line, practically equally distant from S1 and S8, and half way between where their azimuths cut this line. This line was then projected back to cut the azimuth line a_1 from S8. By good fortune this point was where a_1 from S2 also cut. We hence have much confidence in the line as chosen. The height of the beginning point was then calculated on h_1 as seen from S8, and the height of the end point on the combined values of h_2 as seen from S1 and S8. A profile drawing of the path was then made and it is found that the height of the first point seen from S1, based upon h, is only 3 km above the chosen path, and the explosion point based upon the altitudes as observed from S1 and S8 combined is only 2 km below the path chosen. A better result in such work is hardly to be hoped for. The following table gives the usual data:

Date	1950 Sept. 4, 8:54 P.M., E.S.T.; G.M.T., Sept. 4.58
Sidereal time at end point	301°.6
Began over	λ 71° 13′, ϕ 41° 34′ at 105 km
Exploded over	λ 70° 44′, ϕ 41° 52′ at 47 km ± 0.9
Ended over	λ 70° 25′, ϕ 41° 56′ at 35 ± 0.7 km
Length of path	103 km
Projected length of path	77 km
Observed velocity	29 km/sec
Radiant (uncorrected)	a_1 58°.5, h_1 42°.5, α_1 262°.0, δ_1 + 9°.5
Zenith attraction (parabolic)	7° 12′
Radiant (corrected)	a_1 58°.5, h_1 35°.3, α_1 257°.2, δ_1 + 3°.8
Orbit (parabolic)	
ι	22°
☊	162°
π	208°
☿	0.15 A.U.

The estimates of duration are 2, 3, 3, 5, 5 seconds. But apparently S1, which gives 5, did not see all of the path. However, taking the estimates as they are we get an average duration of 3.6 seconds, which obviously has a large probable error. The body seems to have been blue-green-white or some combination until the flare or explosion after which it became more orange. Some sparks were thrown off at that point.

Though unusual that more persons did not report this bright fireball that passed early in the evening over a densely populated area, yet we are very fortunate in that two trained observers, as well as several others, did send in enough to permit a solution in which one can have considerable confidence. I am under many obligations to each individual, and to Dr. F. L. Whipple of Harvard for lending me the two reports which were received there. In conclusion, I wish again to point out that the solution of each fireball path is a problem in itself and often requires unusual steps. This means that the person who computes it must use much personal judgment. The results therefore are approximate, yet, uncertain as they often are, the percentages of probable error in them would compare most favorably with those found in the best lists of photographic parallaxes, and these latter are the very basis of stellar astronomy.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pa.
1951 November 12.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By MARGARET W. MAYALL, Recorder

The AAVSO at Harvard. The 40th Annual Meeting of the AAVSO was held at the Harvard Observatory on October 12 and 13, 1951. Nearly 100 members and guests turned out for the gala celebration of the 40th Anniversary of the Association.

A large group gathered in the Observatory Library on Friday evening to hear Dr. Bart J. Bok speak on "Astronomy under the Southern Cross." Dr. Bok had just returned to Cambridge after a year and a half at the Harvard Observatory station in Bloemfontein, South Africa, and regaled the audience with many stories of his experiences with South African animals, astronomers, and telescopes. It was interesting to get first-hand information about our southern observers, such as Reginald de Kock, S. C. Venter, and Peter Kirchhoff. Everyone was delighted to see examples of the wonderful sculpture by Dr. Kirchhoff.

Dr. Bok had many pictures of the installation of the Armagh-Dunsink-Harvard telescope, the 36-inch Baker-Schmidt, which is proving to be a very successful instrument.

Dr. and Mrs. Shapley invited the members of the AAVSO to a party in the Residence after the lecture. The Shapleys were entertaining the "Neighbors," who were meeting at Harvard over the weekend, and the two groups had a chance to get acquainted at the party. The members of the Occultation Committee were particularly delighted to have a chance to meet and talk with Mr. D. H. Sadler, Superintendent of H. M. Nautical Almanac Office, who takes care of all reductions of occultations. Mr. Sadler was introduced by Dr. Dirk Brouwer to the meeting on Saturday morning, when he gave a short talk about the importance of occultations and the future plans for reductions.

The AAVSO Council met on Friday afternoon to discuss the business of the Association. Four new life members and eighteen new annual members were elected.

LIFE

Francis K. Czyzewski, South Bend *Tribune*, South Bend, Indiana
Theodore Dunham, Jr., 234 Castleman Road, Rochester 7, New York
Leo A. Kelley, 3438 87th Street, Jackson Heights 72, New York
Allan J. Way, P.O. Box 48, Newcastle West, N.S.W., Australia

ANNUAL

Curtis E. Anderson, 1000 3rd Avenue N.E., Minneapolis 13, Minnesota
P. K. Banerjee, P.O. Panihati (24 Pargs.), West Bengal, India
J. G. Goodsell, 1114 Windsor Place, South Pasadena, California
Walter La Vaughn Hales, Route 5, Boaz, Alabama
Palmer Harris, 101 N. Spring Garden Avenue, Nutley 10, New Jersey
Katharine H. Hendrie, 256 Eliot Street, Milton 87, Massachusetts
Juan Homero Hernandez, Zamora No. 50, Veracruz, Ver., Rep. de Mexico
Roy R. Lee, 431 Emery Street, Longmont, Colorado
Howard A. Le Vaux, 910 South Wooster Street, Los Angeles 35, California
Kim Malville, 135 Magellan Avenue, San Francisco 16, California
William G. Mebius, 31 Floyd Road, Verona, New Jersey
Edwin A. Olson, Hollis, New Hampshire
Richard C. Otter, 124 Township Line, Jenkintown, Pennsylvania
Barry Parker, 903 Conklin Avenue, Penticton, B. C., Canada
Leo Plamondon, 827 Gervais, Trois-Rivieres, Quebec, Canada
Roger E. B. Randall, 16 Netta Road, Dedham, Massachusetts
William A. Reid, 167 South Avenue, Hawthorne, New Jersey
Richard T. Windsor, P.O. Box 468, Edinboro, Pennsylvania

The Recorder read a list of 23 papers to be presented at the General Meeting on Saturday, as follows:

Summary of History of AAVSO since 1936—David W. Rosebrugh
The Influence of Sunspots on Climate—Leith Holloway
A New Inexpensive Filter for Observing the Sun with Any Reflector—Stanley L. Brower
The Gremlins and My Photometer—J. J. Ruiz
Deformations on the Sun's Limb—Ralph N. Buckstaff
Granulation Characteristics of the Minimum Sunspot Period—James C. Bartlett
Preliminary Report on the Results Obtained from the Observations in the Foreshortening Project—Dr. W. Gleissberg
Revised Procedures for Reducing Sunspot Number Observations—Alan H. Shapley
On the Apparent Asymmetry in the Distribution of Sunspots (New Project)—Dr. W. Gleissberg
Auroral Index as an Evaluation of an Auroral Display—Donald S. Kimball
An Exposure Formula for Solar Photography—Harry B. Chase
Observing Inferior Conjunctions of Venus and the Sun—Cyrus F. Fernald
Further Tests on Planetary Details—David W. Rosebrugh
The Leon Campbell Observatory—Dr. Harlow Shapley
Making the New Southern Charts—Roy A. Seely
AAVSO Charts on Slides—John Streeter
A Class Method for Teaching Variable Star Estimating—Donald S. Kimball
The R Lyrae Curve—Jeremy H. Knowles
A Different Kind of Light Curve—Clinton B. Ford
Light Curves of Z-1256 in 1950 and 1951—Ralph N. Buckstaff
What to Do with a New Variable—Joseph Ashbrook
Two Problems Facing the AAVSO—David W. Rosebrugh
Zwicky's Nova Aquilae 1951—Dorrit Hoffleit

The annual business meeting of the Association was held on Saturday morning, and reports from all the committees were read. The announcement was made of the receipt of $500, a bequest from William Tyler Olcott, which was paid to the Association after the death of Mrs. Olcott. The members present stood for

a moment of silence while the Recorder read a list of eight members who had died during the year: Leon Campbell, Mrs. William Tyler Olcott, Hans Gaebler, Miss Lois Slocum, Lincoln Ellsworth, Dr. Curvin H. Gingrich, Dr. J. S. Paraskevopoulos, and H. B. Rumrill.

Balloting for new Council members resulted in the election of the following members for 1951-1953: James C. Bartlett, Jr., Thomas A. Cragg, Jocelyn Gill, and Emil A. Sill.

At a meeting of the old and new Council members, the following officers were elected for the year 1951-1952:

President:	Martha Stahr Carpenter
First Vice-president:	Donald H. Menzel
Second Vice-president:	Joseph Ashbrook
Secretary:	Clinton B. Ford
Treasurer:	Percy W. Witherell
Recorder:	Margaret W. Mayall

The Chart Curator, Mr. Richard W. Hamilton, gave his excellent report of activities during the year. He made 214 mailings of charts and atlases, 22 of which went to 14 observers in 12 foreign countries. He has also spent much time revising chart headings to give 1950 positions of the variables, instead of 1900 positions. Mr. Roy A. Seely has completed charts for about 70 of the southern variables to be added to the AAVSO program under the sponsorship of the International Astronomical Union. In addition, Mr. Seely has been working with Mr. Edward Oravec on charts for some of the bright variables, for naked eye or binocular observations.

The Solar Division, under the chairmanship of Mr. Neal J. Heines, is one of the most active branches of the AAVSO. There are now 163 members scattered over 33 states, with 12 in foreign countries. The Solar Division collaborates with the Central Radio Propagation Laboratory of the National Bureau of Standards in the determination of the American Relative Sunspot Numbers.

The Recorder's report showed a drop in the total number of observations (48,291) received, probably due to the excessive number of cloudy nights throughout the year. But the observations were well distributed, and few light curves suffered for lack of observations. Reports were sent in during the year by 136 observers, 23 of whom contributed regular monthly reports, 4 sent in 11, and 36 others sent from 5 to 10 reports each. Our South African Honorary Member, Reginald P. de Kock, took first place for the year in the number of observations submitted, with 5,963 observations. In second place is Cyrus F. Fernald, of Wilton, Maine, with 3,774 observations, and in third place is Leslie Peltier, of Delphos, Ohio, with 1,950. Eleven others contributed more than 1000 observations each: Oravec, New York, 1,913; Hartmann, New York, 1,788; Renner, Ohio, 1,781; Greenley, New Jersey, 1,715; Galbraith, California, 1,625; Peter, Switzerland, 1,603; Adams, Missouri, 1,536; Rosebrugh, Connecticut, 1,324; Ahnert, Germany, 1,281; Meek, New Mexico, 1,262; and Taboada, Mexico, 1,020. Fifty observers located in 20 countries outside the United States contributed 20,188 observations, or 42% of the year's total.

Mr. Donald S. Kimball, Chairman of the Auroral Committee, gave a most interesting report of the renewed activity of the committee. Mr. Kimball has prepared instructions for observing aurorae and a new form for reports. He is working in collaboration with Dr. Gartlein of Cornell, and the National Bureau of Standards, the U. S. Signal Corps, and the National Geographic Society. He

made a strong plea for more observers, particularly in Canada and the middle and far West.

The papers presented at the meeting were of such variety and of such general interest that Newton Mayall volunteered to abstract them, and we will send copies to members and observers.

The 40th Anniversary dinner of the Association was held at the Hotel Commander. The Toastmaster, Donald H. Menzel, introduced Dr. Shapley, and asked him to give his annual "Highlights of the Year." They were as follows:

1. Calculation with large digital computing machines of the positions of the five outer planets for the interval from 1653 to 2060—the work of Wallace Eckert in the Pure Science Department of the IBM Corporation, with assistance in certain details by G. M. Clemence of the Nautical Almanac Office and Dirk Brouwer of Yale University.

2. The American Academy's Solar Conference in February, 1951—The Sun in the Service of Man—participated in by experts from half a dozen sciences.

3. Measurement of the motion of hydrogen nuclei (protons) in the aurora borealis, measured by A. B. Meinel of the Yerkes Observatory with a special spectrograph; velocities up to 3300 km/sec, indicating that protons are the source of much, if not all, the energy for auroral displays.

4. Rapid progress in radio astronomy by the radio engineers (electronic physicists) at Manchester and Cambridge in England, Sydney, Australia, and Leiden, Holland, with the number of radio "stars" brought up to more than one hundred, radiation in microwave region detected from three or four of the brighter spiral galaxies, and much progress made in the measurement of microwaves from the solar surface.

5. The setting into operation of two special types of Schmidt telescopes—the ADH instrument at the Boyden Station in South Africa (a Baker-Schmidt) and the Super-Schmidt (also Baker design) for the meteor expedition in New Mexico —both operations associated with the Harvard Observatory.

6. The prediction and measurement of radiation from neutral hydrogen in various parts of the Milky Way, the relevant emission lines being of extraordinary wavelength—21.3 cm; the theoretical prediction from the work of I. I. Rabi and his associates at Columbia University, Purcell of Harvard University, and van de Hulst of Leiden, with the first detection and measurement of this remarkable radiation by Dr. Ewen of the Harvard Physics Department, whose work has been followed especially in Holland, but also in Australia by others who have established this special microwave radiation as a new tool for exploring the properties of the Milky Way.

7. Measurement by Dr. John Hall of the Naval Observatory of the polarization of light from one (and one only) of the Pleiades—an A-type star highly reddened by light scattering in the path between the star and the observer.

8. Discovery by Dr. Thackeray of the Radcliffe Observatory, Pretoria, South Africa, of 216 new variable stars in the so-called Sculptor cluster—a wide open spheroidal galaxy of the local family, and the prediction by Thackeray that the total number would probably run over seven hundred; the discovery is important in verifying a longstanding surmise that the population characteristics of spheroidal galaxies and globular clusters are much alike.

9. A newly developed theory of the ice ages by Dr. Ernst Öpik of the Armagh Observatory, North Ireland, in which he attributes both the Paleozoic

and the Pleistocene glaciations to changes in the radiation of the sun—changes that result from temporary disturbance in the production of atomic energy radiation deep in the solar interior.

10. The measurement by Dr. Milton Humason with the 200-inch Palomar reflector of radial velocities of external galaxies that are more distant than any heretofore measured; with a 4- to 6-hour exposure and spectra 2 mm long, he deduces a maximum speed of 38,000 miles a second, which is about one-fifth the speed of light.

11. The demonstration by physicists at the University of Minnesota and Rochester University that primary cosmic radiation is composed of the nuclei of the elements from hydrogen to iron and beyond, with the hydrogen nuclei (protons) dominating the radiation. It has been measured through the penetration of photographic films that have been sent by balloons to an altitude of 100,000 feet, where the measures are essentially clear of the secondary cosmic radiation with which we are familiar at the surface of the earth.

In addition to the highlights of the year, Dr. Shapley mentioned what he considered could be called the highlights in astronomy of the first half of this century. He offered the following seven items—not in order of importance:

1. Relativity theory and practice
2. Quantum theory and its atomic-transmutation consequences
3. Star streaming and the subsequent galactic rotation operation
4. Identification of the Magellanic Clouds and the extra-galactic nebulae as Milky Way systems
5. Development of photometric methods of measuring stellar distances (period-luminosity relation, maximum luminosities, and subsequent re-orientation of galactic structure)
6. The boom in astronomical instrumental developments, both conventional (large reflectors) and unconventional (Schmidt-type, coronagraph, photo-tube accessories)
7. Stellar radiation interpretations (Emden, Ritter, Schwarzschild, Eddington, Russell-Hertzsprung)

The discussion that followed showed that the professionals and amateurs present agreed with his selection. Dr. Bok and Dr. Menzel both pointed out that Dr. Shapley, himself, has had a hand in many of the developments.

A highlight of the 40th Anniversary meeting was the presentation of two Merit Awards. Mr. Fernald, the recipient of the 9th Merit Award in 1948, presented the 11th Award to "David W. Rosebrugh, who has devoted untold hours to the visual observation of variable stars, and to administrative duties during his terms as Secretary and President of the Association." Then the Recorder had the privilege, on this 40th Anniversary of the AAVSO, of presenting the Tenth Merit Award to "Harlow Shapley, on the occasion of his Thirtieth Year as Director of the Harvard College Observatory and guiding light of the Association, and for his international recognition in the field of variable stars."

Mr. Rosebrugh had to pay for his Merit Award by acting as Quiz Master for a Panel of Experts, composed of Dr. Shapley, Mrs. Gaposchkin, Dr. Ashbrook, Mr. Streeter, Dr. Herget, Dr. Wood, and Miss Farnsworth. The questions Mr. Rosebrugh pulled from the box ranged from very serious ones, which could require lectures of several hours, to those not so serious. But the members of the Panel showed themselves to be real experts and were not stumped.

The meeting ended with a showing of movies taken by Mr. Ford at recent AAVSO meetings, and a gracious "Thank you" by Miss Henrietta Swope.

Special Note. The R Coronae Borealis type variable, 054319 SU Tauri, is beginning to show activity after a maximum which has lasted since the middle of 1945. Its mean magnitude has been about 9.5, but the observations of the last month show a slow drop to about 11.0.

Observations received during October 1951. A total of 4,854 observations was contributed by 65 observers, as follows:

Observer	No. Var.	No. Ests.	Observer	No. Var.	No. Ests.
Adams, R. M.	51	159	Kelley, L. A.	5	6
Ahnert, P.	41	468	Kelly, F. J.	10	10
Ancarani, M.	17	18	Kirchhoff, P.	30	51
Anderson, C. E.	2	2	Knowles, J.	15	65
Bicknell, R. H.	17	102	de Kock, R. P.	145	597
Blunck, V. H.	5	8	Le Vaux, H. A.	39	41
Bogard, D.	36	53	Luft, H. A.	7	21
Boone, A.	9	9	Melville, E. C.	8	12
Boutell, H. G.	5	20	Miller, W. A.	61	110
Buckstaff, R. N.	14	42	Morrisby, A. G. F.	26	26
Cain, C. V.	3	3	Motley, G.	40	60
Charles, D. F.	18	21	Oravec, E. G.	84	177
Cooke, S. R. B.	21	47	O'Sullivan, W. H.	11	29
Cragg, T. A.	78	90	Overbeek, M. D.	23	44
Dafter, R.	8	19	Owen, T.	4	11
Darling, B.	32	108	Parker, P. O.	20	20
Darnell, P.	2	7	Pearcy, R. E.	34	35
Darsenius, G.	43	160	Peltier, L. C.	63	274
Diedrich, DeL.	3	3	Pierson, E. W.	91	100
Diedrich, G.	7	11	Reeves, W. P.	2	6
Fernald, C. F.	172	258	Renner, C. J.	192	192
Fernald, E. S.	4	4	Rosebrugh, D. W.	25	224
Ficonetti, R.	9	17	Sherman, R. L.	15	33
Fisher, Y. W.	1	27	Sill, E. A.	28	28
Ford, C. B.	100	113	Stevens, W. A.	11	11
Galbraith, W. H.	52	220	Tarbell, E. D.	3	16
Greenley, R. M.	83	154	Tarwater, C.	15	27
Hartmann, F.	144	173	Tifft, W. G.	3	7
Hernandez, J. H.	2	2	Upjohn, L. N.	34	34
Herring, A. K.	24	26	Venter, S. C.	46	130
Holloway, J. L.	5	5	Weber, J. A.	27	27
Howarth, M.	20	37	Whitehill, S. L.	4	4
Jerabek, H. S.	11	40			

Nova Search. Reports on the Nova Search Program were received during the month from nine observers, as follows:

Observer	Area	No. Nights	Mag.	Observer	Area	No. Nights	Mag.
Adams, R. M.	16, 17, 39, 40, 57, 58, 86, 87	4	8	Darsenius, G.	Dome	2	2
					Dome	8	1
	16, 17, 39, 40, 57, 58, 86, 87	1	7		16	6	6
					16	4	5
Blunck, V. H.	8, 9, 10	3	6		17	9	5
					17	1	4

Observer	Area	No. Nights	Mag.	Observer	Area	No. Nights	Mag.
Diedrich, DeL.	40	1	4		18, 63, 65	2	5
Diedrich, G.	Dome	2	2		18, 63	3	4
	78	2	6	Rosebrugh, D. W.	Dome	8	3
Luft, H. A.	28, 29, 30	4	5		1	5	4
	33, 34, 35	1	5		34	4	4
Rick, L.	Dome	3	2	Smith, F. W.	3, 4	9	6
	Dome	2	1				

November 8, 1951.

Comet Notes

By G. VAN BIESBROECK

During the month of October, three faint comets were added to the nine that had been discovered already this year.

COMET AREND (1951 *j*)—The central bureau of telegraphic information at Copenhagen reported the discovery of this object on October 8. It was found on plates taken October 4 by S. Arend at the Royal Observatory, Uccle, Belgium. This very active observer was already responsible for the discovery of the second new comet 1951 *b* of this year. The first information was as follows:

1951 Oct. 4.90632 U.T. $1^h 2^m 4 + 23° 27'$ Magnitude 14
Daily motion $1^m 6^s$ west, $0° 16'$ north.

The object was described as being diffuse, having a nucleus but nothing was reported about a tail. It was recorded again on October 6 and 8 by the discoverer so that L. E. Cunningham, Berkeley, California, was able to secure the following orbit, one week after the discovery:

Perihelion passage	1951 Nov. 12.71506 U.T.
Node to perihelion	39°.475
Longitude of node	357.452 1951
Inclination	21.212
Eccentricity	0.51295
Perihelion distance	1.82 A.U.
Period	7.2 years

This is therefore an addition to the list of short-period comets even though the period is necessarily uncertain since it depends on a time interval of four days only. The preliminary ephemeris is as follows:

	h m	° ′	m
Oct. 31	0 29.9	+29 26	14.0
Nov. 10	22.0	30 45	14.1
Nov. 20	0 18.8	+31 44	14.2

This ephemeris shows that the comet will remain very well situated in the constellation of Andromeda but hardly become brighter than at discovery. Observations in October have shown that, although the elements will require some adjustment, they are essentially correct. Herewith is reproduced an enlargement of the image of the comet obtained November 4 at the prime focus of the 82-inch reflector of the McDonald Observatory. This 10-minute exposure shows that the sharp, nearly stellar nucleus is surrounded by a diffuse coma which extends in a broad fan-shaped tail towards position angle 140 degrees. On the original plate

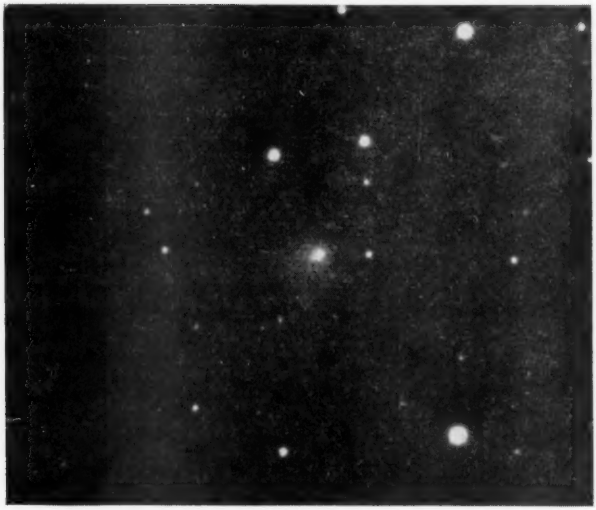


FIGURE 1
COMET AREND (1951 *j*)

this tail extends to 2 minutes of arc from the nucleus. Since this observation was made within a week from the date of the nearest distance from the sun, no further physical development of the comet is to be expected but it will be observable for some time with larger instrumnts.

COMET HARRINGTON (1951 *k*) was discovered the same night as 1951 *j* at the Palomar Observatory, California, on plates taken with the 48-inch Schmidt telescope making the National Geographic Society Sky Survey. It will be remembered that this same observer was co-discoverer of COMET 1951 *i* this summer. The discovery was reported as follows on October 9:

1951 Oct. 4.30090 U.T. $0^h 44^m 0 + 37° 11'$ Magnitude 16
Daily motion $0^m 26^s$ west, $0° 7'$ south
Diffuse with central condensation, tail less than 1° in length

Like the previous object, this comet was also situated in the constellation of Andromeda. The announcement came near the time of full moon so that no further observations of this faint object were possible. Nothing more has been heard about this evidently very distant object.

PERIODIC COMET SCHAUMASSE (1951 *l*)—This expected periodic comet was first recorded on plates taken September 30 by L. E. Cunningham with the 60-inch reflector of the Mt. Wilson Observatory in California. It was then as faint as 18.6 magnitude and the position showed that the time of perihelion 1952 February 9.506 predicted by M. Sumner (*B.A.A. Handbook 1951*, p. 47) required a correction of +1.169 days to bring the ephemeris in better agreement with the measures.

This comet, which was first discovered in 1911, has a period of 8.2 years; it has been seen at each return since then except in 1935. During the present

apparition the comet will be favorably located this winter as can be seen from the following ephemeris:

		h m	° ′	m
1951 Nov.	30	6 27.3	+18 30	15.4
Dec.	10	36.4	21 43	14.7
	20	45.5	26 28	14.1
	30	6 56.1	33 00	13.6
1952 Jan.	9	7 11.3	41 6	13.2
	19	7 36.0	49 45	12.8
	29	8 16.0	+57 11	12.7

But at maximum the comet will not be brighter than 12.7 magnitude.

With larger instruments a number of faint comets previously discovered can still be reached. Periodic comets KOPFF and TEMPEL were recorded here last on November 3 at low altitude in the evening twilight. The faint periodic comets NEUJMIN (1951 *g*) and COMAS SOLA (1951 *h*) are close to their predicted positions and magnitudes (November 4). In the morning sky COMET MINKOWSKI (1950 *b*) comes again in better position. It appeared as a 14 magnitude object on November 4, close to the ephemeris by J. Bobone. It is not expected to become any brighter, but observations will be possible yet for several months so that the period of visibility of this comet discovered 1950 May 18 will be very long.

McDonald Observatory, Fort Davis, Texas, November 5, 1951.

General Notes

Dr. C. H. Hins, astronomer at the Leyden Observatory, was killed in a traffic accident in Leyden, Netherlands, on October 21, 1951.

Dr. Robert Grant Aitken, Director Emeritus of the Lick Observatory of the University of California and one of the world's greatest and best-known astronomers, died in Berkeley, California, on October 29, 1951, at the age of 86 years.

Curvin H. Gingrich Lecture Fund Established

This fund was established in 1951 by former members of Dr. Gingrich's classes in mathematics at Carleton College.

The income is to be used each year to bring an eminent authority to the college to give a lecture or series of lectures and to confer with interested students and faculty. The principal aim will be to secure men or women especially gifted for their capacity to interpret the role of science and of the Christian culture in our civilization.

Contributions may be made to Carleton College and designated for this Fund.

Ephemerides of Bright Minor Planets for 1952 Available

The Cincinnati Observatory announces that their ephemerides of bright minor planets are available to interested amateurs. Requests should be directed to the Cincinnati Observatory and a self-addressed envelope should be enclosed.

Ruins of Tycho Brahe's Observatory Protected

The Swedish National Committee of Astronomy announces that the ruins of Tycho Brahe's observatory Stajärneborg on Ven have again been excavated and

are now protected by a building. A ceremony was held there on October 27 in memory of Tycho Brahe's death on October 24, 1601.

Provisional Sunspot Numbers for October, 1951*

1	41	11	81	21	43
2	44	12	95	22	32
3	43	13	72	23	20
4	38	14	52	24	10
5	31	15	63	25	21
6	19	16	67	26	41
7	16	17	56	27	55
8	25	18	58	28	71
9	54	19	81	29	73
10	71	20	78	30	72
				31	70

Mean Value October
R = 51.4

*From the Zürich Observatory, furnished by Mr. Neal J. Heines.

Book Reviews

200 Miles Up, by J. Gordon Vaeth. (The Ronald Press Company, 15 East 26th Street, New York 10, N. Y. 207 pp. $4.50.)

This interesting book gives an excellent description of the possibilities of research in our upper atmosphere and of the different vehicles that carry the scientific instruments to the desired height. A large number of illustrations helps the imagination of those readers, who never saw the high-altitude balloons and rockets in actual flight.

The author starts with an analysis of the physical phenomena of interest in the atmospheric ocean and discusses the upper-air research instruments of which many have to transmit their information by telemetering devices to the ground stations. The vehicles, which carry these instruments to the desired height, are discussed, namely the high-altitude balloons and high-altitude rockets. More in detail the skyhook balloon and the rockets V2, aerobee and viking, are described.

Skyhook balloons are often misinterpreted as "flying saucers," and therefore an authentic report of a crew, observing a routine flight of a skyhook balloon on April 24, 1949, in the New Mexico desert, is very interesting. They discovered an elliptical object near the balloon and could follow it in the theodolite. The rapidly moving object disappeared in a sharp climb after being visible about one minute. Fifteen minutes later another weather balloon was sent up to check wind values. It proved that the unidentified object could not have been a balloon moving at such angular speed below 90,000 feet. The object was seen under conditions of a cloudless sky and no haze.

This book is also of value for those interested in space travel outside our atmosphere, because it gives an accurate account of the practical possibilities today. A manned space rocket will only become a reality when the many problems involved are investigated and solved.

Goodsell Observatory, Carleton College. L. BINNENDIJK.

A History of the Theories of Aether and Electricity. The Classical Theories, by Sir Edmund Whittaker, F.R.S. (Thomas Nelson and Sons, 385 Madison Avenue, New York 17, N. Y. 434 pp.)

In this first volume of a two-volume treatise, the author traces the history of optics, electricity, and electromagnetism through the work of Lorentz. A description and analysis of the modern theories in these areas is to be presented in a companion second volume.

In general, the chapters follow an approximate chronological sequence. A discussion of optics is begun with Kepler and is carried through Huygens and Newton, before the researches and theories of Gilbert and his early successors in magnetism and electricity are presented. In succeeding chapters, the scene shifts from Coulomb, Galvani, Oersted, Ohm, and others to Bradley, Young, Fresnel, Cauchy and Rayleigh (to mention only a few)—then back again to Faraday, Weber, Joule, and Kirchhoff. The two streams of thought and experimental effort finally unite in the work of Maxwell. The final chapters of the book cover the last two decades of the nineteenth century with their emphasis on electromagnetic waves, conduction in gases and liquids, and classical radiation theory, together with those discoveries that determined the pattern of early twentieth century physics: X-rays, the electron, the Zeeman effect, and photo-electricity.

The presentation throughout the book is lucid and thorough. There is a generous quotation from original papers and extensive footnote references to the original sources. The mathematical analysis of the early theories sometimes uses a modern notation; what this approach lacks in historical accuracy, it gains in clarity. The reader marvels at the careful and precise work done with equipment which would not be acceptable today in even an elementary physics laboratory. He shares the excitement of successes and the frustration of inconsistencies between theory and experiment.

This first volume deserves a prominent place on the reading list of physics teachers; graduate and advanced undergraduate students will find reading it rewarding. The publication of the second volume is eagerly awaited.

Carleton College. FRANK VERBRUGGE.

British Scientists, by E. J. Holmyard. (Philosophical Library, Inc., 15 East 40th Street, New York 16, New York, 1951, 88 pp. $2.75.)

This book contains 24 excellent portraits of famous British scientists and a summary of their scientific work. The limited space in the book prevents a more detailed description of the work and lives of these scientists. Fortunately a bibliography is given at the end of the book so that the interested reader has the references available for further study. A short history of British scientific societies is also given.

Goodsell Observatory, Carleton College. L. BINNENDIJK.

Eddington's Principle in Philosophy of Science, by Sir Edmund Whittaker. (Cambridge University Press, 1951. 35 pp.)

This is the content of the fifth Arthur S. Eddington Memorial Lecture given by Sir Edmund Whittaker at Cambridge on August 9, 1951. This lectureship was instituted in 1947, one year after Eddington's death and its purpose was "to deal with some aspects of contemporary scientific thought considered in its bearing on the philosophy of religion and ethics." The four previous lectures were: 1.

Reflections on the Philosophy of Sir Arthur Eddington by A. D. Ritchie; 2. *Sir Arthur Eddington: Man of Science and Mystic* by L. P. Jacks; 3. *The Unity of Knowledge* by George B. Jeffery; 4. *Creative Aspects of Natural Law* by R. A. Fisher. The fifth lecture deals with what Edmund Whittaker calls "Eddington's Principle" which can be stated in the following words: "All the quantitative propositions of physics, that is, the exact values of the pure numbers that are constants of science, may be deduced by logical reasoning from qualitative assertions, without making any use of quantitative data derived from observation." By quantitative propositions are meant all quantitative assertions about nature, for instance: an electron has a radius 10^{-13} cm; the velocity of light is 3×10^{10} cm, etc. On the other hand, all other assertions in which no reference is made to any particular number are called *qualitative;* the principle of constant velocity of light, *i.e.,* its independence of the motion of the source of light is, according to Whittaker, an example of a qualitative proposition. The meaning of Eddington's Principle is illustrated by an example taken from geometry: from purely qualitative assumptions, that is, from the axioms of Euclidean geometry, it is possible to obtain the numerical value of π to any degree of accuracy. In such a short lecture, the author obviously does not pretend to present any exposition of Eddington's Principle, but he rather tries to emphasize its philosophical and epistemological aspects. He shows that Eddington in his belief that the qualitative attributes of nature are prior to the qualitative ones follows the tradition of Leibniz. This belief led Eddington to conceive the numerical constants of nature not as ultimate irreducible facts which are mutually independent and which have to be simply accepted, but as consequences derivable from more basic features of the physical world which can be stated in propositions not containing any particular numbers. Hence the persistent efforts of Eddington to discover the relations between apparently independent numerical constants of nature: Planck constant, the velocity of light, the mass of an electron, the mass of a proton, the mass of the universe. By "qualitative" Whittaker does not mean non-mathematical; on the contrary, he, like Sir James Jeans, considers the mathematical order of the physical world as the only permanent feature of nature; he goes even further in claiming on the basis of modern cosmogonical theories that the world began in time and will end in time while its ideal mathematical pattern, which preceded it, will eventually survive it too. This identification of the mathematical order with God is probably the least original part of the lecture, because it is really a pet idea of philosophers and physicists since the seventeenth century; consequently, it implies a definite return to the past, and it is only natural that more recent philosophical as well as religious views like, for instance, those defended by Whitehead in *Process and Reality,* find little sympathy with the author.

Carleton College. M. Capek.